HUMAN HISTOLOGY

IN ITS RELATIONS TO

DESCRIPTIVE ANATOMY, PHYSIOLOGY, AND PATHOLOGY.

With Four Hundred and Thirty-Four Illustrations on Wood.

BY

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"Maxime in minimis."

PHILADELPHIA:
BLANCHARD AND LEA.
1857.

PHILADELPHIA:
T. K. AND P. G. COLLINS, PRINTERS.

TO

R. D. MUSSEY, M.D., LL.D.,

WHOSE PROFESSIONAL SKILL, SCIENTIFIC ACCURACY,

AND MORAL INTEGRITY,

INCITED THE AUTHOR'S FIRST DESIRE TO ENTER

THE MEDICAL PROFESSION,

This Work

IS MOST RESPECTFULLY INSCRIBED.

PREFACE.

THE plan of the following work was formed nine years ago; since which time the author's annual courses of lectures have been arranged in accordance with it. Meantime several works have appeared in Germany, France, and England, upon the subjects embraced in it; but no one including its entire aim, viz:—

I. *To give a connected view of the simple chemical elements, of the immediate principles, the simple structural elements, and the proper tissues, entering into the composition of the fluids and the solids of the human body.*

II. *To associate with the structural elements and the tissues, their function while in health, and the changes they undergo in disease.*

In the prosecution of his object, the author has drawn more especially upon the work of Robin and Verdeil in the first part; that of Lehmann in the division including the fluids; and on Kölliker's excellent work in the part on the tissues proper. He has not hesitated, indeed, sometimes to use the language of the latter, when sufficiently concise. He has not, however, embarrassed the text by references to the various authorities whence materials have been derived; except in instances where views varying from those of previous writers are advanced, as being, in the author's judgment, the most satisfactory at the present time.

In regard to the dimensions of the minute structural elements, Kölliker has been more especially relied upon. And as this work is intended especially for those who use the English language, they are given in fractions of an inch, instead of a millimetre, or a Paris line, as has usually been done by translators of German and French works, both in England and in this country.

An experience of sixteen years as a public teacher of anatomy, physiology, and surgery, has confirmed the author's conviction that the only rational method of imparting a knowledge of *function* is by associating with the latter all that is known of the forms and relations of the structural elements, and of their chemical composition, in each part and organ. Pathological anatomy, moreover, and therefore pathology, can be rationally understood only as we take the same point of departure. As the student should, however, study the last mentioned departments after acquiring a knowledge of the healthy structure and functions, the pathological conditions of the tissues are, in the present volume, specified in closer type; as intended to be more especially studied on a second reading of the work. The same remark also applies to the parts which concern the structure of the lower animals.

Some typographical errors, overlooked in the pressure of other professional occupations, will be corrected at once by the intelligent reader; excepting, perhaps, those referred to at the end of the volume. Some portions compiled for it, relating to pathological and comparative histology, have also been omitted, to avoid rendering it formidable, from its size, to medical students; to whom, and to the profession, it is submitted as the first American work on the subjects of which it treats.

NEW YORK, *October*, 1857.

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GENERAL REMARKS.

THE human body, when fully developed, is composed of solids and fluids, in the proportion of one of the former by weight to at least eight or ten of the latter.[1] All the solids are permeated to a greater or less extent by the fluids, of which, also, water is always the principal constituent. The mere descriptive anatomist regards the solids alone, as if isolated from the fluids which form an essential part of them. But the chemical physiologist and the histologist must study the latter as well as the former. The isolated fluids, also, as the blood, chyle, milk, and other secretions, come within the domain of histology so far as they contain cells, granules, nuclei, or other histological elements; and these, therefore, as well as the tissues, will be embraced in this work.

Commencing, however, with an analysis of the human body as seen by the unaided eye, and omitting for the present the isolated fluids, we find that it is composed—

1. Of parts and organs.
2. That the organs are formed of combinations of *tissues.*
3. The tissues are composed of certain chemical compounds called *immediate principles.*
4. And the last are formed by a direct combination of a few of the *simple chemical elements.*

Reversing this view, we perceive that—

1. The simple elements unite to form the immediate principles.
2. The last unite to form the tissues.

[1] A mummy of a native of Teneriffe, presented to Blumenbach by Sir Joseph Banks, weighed but seven pounds and a half; probably not more than one-sixteenth of the weight of the same body during life.

3. And the tissues, separately and in combination, constitute the parts and organs of which the body consists.

This work will, accordingly, consist of two parts—

Part I., containing an account of the simple elements, and of the immediate principles of the tissues and the fluids, or STŒCHIOLOGY.

Part II., giving a description of all the tissues, and the fluids containing histological elements, or HISTOLOGY.

PART I.

STŒCHIOLOGY.

Stœchiology[1] comprises the classification and description of the simple chemical elements, and of the immediate principles which enter into the composition of the tissues and fluids of which the human body is composed.

FIRST DIVISION.

THE SIMPLE CHEMICAL ELEMENTS ENTERING INTO THE STRUCTURE OF THE HUMAN BODY.

Of the sixty-five simple bodies now (1857[2]) known to chemists, it is not certain that more than fifteen are normal constituents of the human body. These are—

1. Oxygen.	6. Phosphorus.	11. Chlorine.
2. Hydrogen.	7. Calcium.	12. Fluorine.
3. Carbon.	8. Magnesium.	13. Silicum.
4. Nitrogen.	9. Sodium.	14. Iron.
5. Sulphur.	10. Potassium.	15. Manganesium.

M. Millon announced that copper and lead also normally exist in the blood-corpuscles of man, and Orfila added arsenic as entering into the composition of the tissues. These observations have, how-

[1] From Στοιχεῖον, an *element*, and λογος, description.

[2] Two or three others have just been announced, but their discovery has not been confirmed.

ever, not been confirmed; and either of these three substances, found in the human organism, must be regarded as accidentally present. Iodine and bromine enter into the composition of the lowest marine animals; but it is not yet proved, nor probable, that they normally form a part of the human body, though such an assertion has been made.

The fifteen elements just mentioned unite variously to form the immediate principles of the tissues hereafter to be considered. The following is, however, a general account of the parts and the fluids in which each is found:—

1–4. The first four elements are found in all the tissues, and most of the fluids, except fat; the first three in all tissues and fluids, without exception. Of the first two water is constituted; whose abundance in the human organism has already been alluded to.

5, 6. Sulphur and phosphorus exist in the albuminous group of immediate principles (albumen, fibrine, &c.), and in the tissues formed from them, and all animal cells. They also enter largely into the composition of the brain—about $\frac{1}{170}$ of its weight being phosphorus. (*Von Bibra.*) Sulphur is a constituent of hair and nails, which accounts for their odor during combustion. Both the sulphuric and the phosphoric acids exist in the urine, and the latter in bones also, in combination with lime and magnesia. Treviranus believed that spontaneous combustion of the human body may be due to an excess of phosphorus in it.

7, 8. Calcium and magnesium are found only in the state of oxides, *i.e.* as lime and magnesia; and combined with acids to form salts. The phosphate of lime constitutes about one-half the weight of human bone, and the carbonate about one-tenth; the phosphate of magnesia amounts to the one-hundredth part. Both these elements also exist in milk, and other fluids.

9. Sodium, in combination with chlorine—*i. e.* forming common salt—exists in every solid and fluid in the body. In all other cases it is in the form of an oxide (soda), and, in combination with acids, forms various salts in the different tissues and fluids.

10. Potassium also unites with chlorine to form the chloride of potassium, the latter being abundant in muscular tissue. Otherwise it is in the oxide state—*potassa*—and in combination with acids. It, however, exists but sparingly in animals, in comparison with soda, while it abounds in plants.

11. Chlorine combines with hydrogen to form the hydrochloric

acid in the gastric fluid. In all other cases it is found as chloride of sodium (common salt), or of potassium.

12. Fluorine is combined with calcium, in small amount, in bones.

13. Silicum exists, oxidized (as silica), in small quantity in the hair, in wool and feathers, and in the urine. It abounds in plants.

14. Iron constitutes about $\frac{1}{2000}$ part, by weight, of the blood; it also exists in hair, muscle, milk, pigment-cells, and (a mere trace) in the gastric fluid. Iron always exists, also, in the feces, since solid and fluid articles of food contain more of it than is required in the organism.

15. The oxide of manganese is found in bone (*Kane*), and, some say, in the coloring matter of the hair. It is separated from the organism in the bile.

Remarks.—1. Our food (and drink) must contain at least the fifteen elements just specified, in order to secure and maintain the development of the body. No single article of food, except milk and eggs, perhaps, contains them all, and hence the necessity for *variety* of aliment.

2. The absurdity of the idea of some, that *minerals* should never be used as remedies, is at once apparent. Ten of the fifteen simple elements are minerals, and the rest, also, all enter into the composition of various mineral substances. We must, therefore, take minerals in all our food, and this whether the latter be animal or vegetable; for all vegetable as well as animal tissues contain mineral substances.

3. Nor is the notion that *no minerals except such as form a part of the body* should be used as medicines, any more tenable, for the same objection would hold against *all* vegetable remedies, since not one of them (opium, lobelia, &c.) naturally enters into the composition of the body; and thus the sole remedies remaining would be the fifteen elements above named; for if it be said that the active principles of vegetables, as morphia, quinia, &c., contain only the elements above mentioned (*e.g.* the four first mentioned), yet it is true that some of these compounds, as strychnia, hydrocyanic acid, &c., are more dangerous and destructive to animal life than any mineral substance known.

SECOND DIVISION.

THE IMMEDIATE PRINCIPLES OF WHICH THE TISSUES OF THE HUMAN BODY ARE COMPOSED.

THE immediate principles of the tissues, are the "last bodies constituting the organism to which the tissues can be reduced by mere *anatomical analysis;* and which admit of no further subdivision without *chemical decomposition.*"[1] Sugar, gum, starch, cellulose, water, &c., are immediate principles to a plant; and water, albumen, fat, urea, &c., to an animal. The carbon, oxygen, hydrogen, &c., composing these are the simple elements, or the elementary (or mediate) principles of the plant, or the animal, respectively.

The expression, "immediate principles," is borrowed from Chevreul, who thus defends its use: "Some scientific writers think this expression objectionable, since it is not reasonable to apply the word *principle* to *compound bodies.* I do not participate in this opinion. For when we consider in a general way the composition of a salt, as established by Lavoisier, it is apparent that it is constituted by the union of an acid and an alkali, rather than by the *elements* of the acid with those of the alkali, since if these elements are united in other proportions than such as constitute an acid and an alkaline body, they no longer give us the idea of a salt. Hence it seems proper to say that the acid and the alkali are the two *immediate principles* of the salts. It is the same with sugar, starch, gum, lignine, &c., in respect to a plant, and with fibrine, albumen, &c., in respect to an animal. These substances should be regarded as the *immediate principles* of the plant or of the animal to which they belong, while oxygen, nitrogen, carbon, and hydrogen

[1] Robin and Verdeil's Anatomical and Physiological Chemistry; 3 vols. p. 1887, with an Atlas. For an extended review of this work, and many of the facts introduced into this division, see the American Medical Monthly, for March, 1855.

are their remote or *elementary principles*."[1] It will appear that the three gases just mentioned are, however, also *immediate principles* in certain circumstances.

Thus the study of the immediate principles of organized bodies is intermediate between mere organic chemistry on the one hand, and histology on the other, and must precede the latter.

CLASSIFICATION OF THE IMMEDIATE PRINCIPLES IN THE HUMAN BODY.

The number[2] of immediate principles in the human body is not precisely determined; but the following classification, embracing 84, may be for the present adopted.

These 84 substances, being all compound except oxygen, hydrogen, and nitrogen, are divided into two groups:—

I. The first group includes those principles which are *crystallizable* or *volatile*, without decomposition. These are divided into two classes:—

1st. Principles of *mineral* origin, 24 in number.

2d. Principles formed within the body by dis-assimilation,[3] and therefore of *organic* origin, 42 in number.

II. The second group includes those which are *not crystallizable*, or *not volatile*, except in consequence of decomposition; only 18 in number. This group is not divided, and constitutes the third class, *organic substances.*

The three *classes* are divided as follows:—

A. Of the *first* class—principles of mineral origin—there are two divisions.

1st. *Gaseous* or *liquid*, and *not saline* bodies, 5 in number.

2d. Saline bodies (salts), 19 in number.

B. The *second* class—principles of organic origin—has four divisions:—

1st. Acid or saline principles, 23 in number.

2d. Neutral nitrogenized compounds, generally called nitrogenized alkaloids, 4 in number.

3d. Neutral *non*-nitrogenized compounds or sugars, 2 in number.

[1] Recherches Chimiques sur les corps gras d'origine animale. Paris, 1823, p. 4–5.

[2] Robin and Verdeil reckon 92 immediate principles in *man and the mammiferæ.*

[3] This word implies the same as the terms "waste" or "metamorphosis" of the tissues.

4th. Fatty and saponaceous compounds, 13 in number.

C. The *third* class—organic substances—has three divisions:—

1st. Substances naturally in a liquid state (7).

2d. Those naturally solid or demisolid (7).

3d. Pigmentary substances, also solid or demisolid (4).

The following table indicates the particular compounds included in each of the classes and divisions just mentioned.

Tabular Classification of the Immediate Principles.

Group I.—PRINCIPLES CRYSTALLIZABLE OR VOLATILE, INDEPENDENTLY OF DECOMPOSITION.

FIRST CLASS.—PRINCIPLES OF MINERAL ORIGIN (24).

First Division. GASEOUS AND NOT SALINE (5).

Oxygen,	Carbonic acid
Hydrogen,	Water.
Nitrogen,	

Second Division. SALTS (19).

Chloride of Sodium,	Sulphate of Soda,
" Potassium,	" Lime,
Fluoride of Calcium,	Basic Phosphate of Lime (Bones),
Hydrochlorate of Ammonia,	Acid Phosphate "
Carbonate of Lime,	Phosphate of Magnesia,
" Magnesia,	Neutral Phosphate of Soda,
" Potassa,	Acid " "
" Soda,	Phosphate of Potassa,
Bicarbonate "	Ammonio-Magnesian Phosphate.
Sulphate of Potassa,	

SECOND CLASS.—PRINCIPLES OF ORGANIC ORIGIN FORMED WITHIN THE BODY BY DIS-ASSIMILATION (42).

First Division. ACID OR SALINE PRINCIPLES (23).

Lactic Acid,	Hippuric Acid,
Lactate of Soda,	Hippurate of Lime,
" Potassa,	" Soda,
" Lime,	" Potassa,
Oxalate of Lime,	Inosate of Potassa,
Uric Acid,	Pneumic Acid,
Neutral Urate of Soda,	Pneumate of Soda,
Acid " "	Taurocholate "
Urate of Potassa,	Hyocholinate "
" Magnesia,	Glycocholate "
" Lime,	Lithofellic Acid.
" Ammonia,	

Second Division. NEUTRAL NITROGENIZED COMPOUNDS (5).
(Nitrogenized *Alkaloids.*)

Creatine,	Urea (and Chloro-sodate of Urea—Urea with marine salt),
Creatinine,	Cystine.

Third Division. NEUTRAL NON-NITROGENIZED COMPOUNDS. SUGARS (2).

Sugar from the Liver,	Sugar of Milk.

Fourth Division. FATTY AND SAPONACEOUS COMPOUNDS (13).

Cholesterine,	Caproate of Potass., Soda, &c.,
Oleic Acid,	Oleine,
Margaric Acid,	Margarine,
Stearic "	Stearine,
Oleate of Soda,	Elaterine,
Margarate "	Stearerine.
Stearate "	

Group II.—PRINCIPLES NON-CRYSTALLIZABLE OR NON-VOLATILE, INDEPENDENTLY OF DECOMPOSITION.

THIRD CLASS.—ORGANIC SUBSTANCES, OR COAGULABLE PRINCIPLES (18).

First Division. THOSE NATURALLY LIQUID (7).

Fibrine,	Pancreatine,
Albumen,	Mucosine,
Albuminose,	Ptyaline.
Caseine,	

Second Division. THE SOLID AND DEMI-SOLID (7).

Globuline,	Cartilageine,
Crystalline,	Ostèine,
Musculine,	Keratine.
Elasticine,	

Third Division. PIGMENTARY SUBSTANCES (4).

Hæmatine, or Hæmatosine,	Melanine,
Biliverdine,	Urrosacine.

In addition to the preceding, may be mentioned[1]—

I. Certain immediate principles of *probable or certain* existence, though not well determined.

1. Of the first class—Silex, in hair, &c., p. 37.

2. Of the second class—Acetate of soda, leucine, xanthine, hypoxanthine, lienine, two acids peculiar to human urine, hæmatoidine. butyrine, butyroline, phosphorized fatty matters of the brain, cerebric acid, and cerebrate of soda.

3. Of the third class, the following are probable: Neurine, syno-

[1] Robin and Verdeil, vol. iii. pp. 415 to 573.

vine, lachrymine, spermatine, organic substance peculiar to dropsical effusions, paralbumine, pyine.

II. Substances known to exist, but doubtful as immediate principles.

1. Of the first class; ammonio-sodaic phosphate; phosphate of ammonia; ditto of iron; chloride of calcium, of magnesium, and of iron; arseniate of lime.

2. Of the second class; tartrate of iron: benzoic acid, and benzoates of soda, potassa, lime, and ammonia; glycocol; hippurate and lactate of ammonia; succinate of soda; urostealite, xanthocystine, urate of iron, sulphocyanuret of potassium, and of sodium; formic acid; a peculiar crystallized principle in semen; butyric acid; uroglaucine; inosite.

3. Of the third class; phymatine; hydatidine; animal substance of calculi; fibralbumine; cyanurine; melanurine; coloring matter of blue suppurations.

III. Certain *simple* bodies whose actual state of combination is unknown, or not generally indicated: iron, copper, lead, manganese, arsenic, sulphur, and the carbon of the lungs. These are also termed medicinal principles.

IV. Certain natural and artificial chemical compounds which are *not* immediate principles. And

V. Substances *called* immediate principles; but which either do not exist at all, or do so as mixtures or products of chemical changes.[1]

First Group.

CLASS FIRST.

IMMEDIATE PRINCIPLES OF MINERAL ORIGIN.

All these principles have a definite chemical composition, the formula for which will be given with the rapid description of each of them which follows.

[1] For these two lists, see Am. Med. Monthly for March, 1855.

FIRST DIVISION.

The gaseous or liquid immediate principles, and those which are not saline.

1. *Oxygen.* (O.)

Oxygen is to be regarded as an immediate principle only when existing in a free state in the body, as in venous and arterial blood, in the air-cells and bronchial tubes, and sometimes in the stomach.

The whole amount of free oxygen in the body averages about $77\frac{1}{4}$ grains, and in the blood alone 61 grains. There are about $9\frac{3}{5}$ cubic inches of oxygen in the arterial blood, and $14\frac{11}{25}$ inches in the venous. But the *proportional* amount is greater in the former than in the latter, in the ratio of 2.41 to 1, and sometimes even of 3 to 1.17; since there is but two-thirds as much blood in the arterial system as in the venous. (*Robin and Verdeil.*)

Oxygen exists in the blood in a *liquid* state (in a state of solution), and probably mostly in the corpuscles alone.

The amount of oxygen received into the lungs of an inhabitant of Potosi, 13,000 feet above the level of the sea, however, equals only *two-thirds* of that consumed by an inhabitant of a maritime city.

The theory of Liebig, adopted by French and German chemists generally, that in the case of the higher animals the oxygen consumed in respiration is destined to combine finally with the tissues and the calorific (respiratory) elements of the food (starch, sugar, fats, &c.), thus forming carbonic acid, water, &c., *for the purpose of producing and maintaining the animal heat*, is evidently too narrow a view of this subject. Heat is the result of nutritive changes of all kinds, but not the direct *object* of them. It is in its action on the tissues of the body, as a vital stimulus, that the prime importance of oxygen consists; though the incidental development of heat, as above stated, is indispensable to the organism.

The quantity of oxygen consumed in a year by an adult male is about 800 pounds.

2. *Hydrogen.* (H.)

Free hydrogen exists normally in the stomach, colon, and cæcum, forming, of all the contained gases, 3.55 per cent. in the first organ, from 5.4 to 11.6 per cent. in the colon, and 7.5 in the cæcum. This

gas is *formed* in the alimentary canal; but precisely how, is not ascertained. There is also a very small quantity of it in the gases expired in normal respiration. None has, however, yet been found in the blood, though the last fact might lead us to expect to find it there.[1]

3. *Nitrogen.* (N.)

Free nitrogen is found in the air-cells of the lungs, in the blood, and the intestinal gases, both healthy and morbid. The whole amount in the lungs and the blood varies from 46.755 to 47.52 grains. In the blood it is *dissolved* and in a fluid state. It constitutes from one-tenth to one-sixth of all the gases in this fluid, and is more abundant in the arterial than in the venous blood (as 1.51 to 1). Animals suffering from emaciation inhale more nitrogen from the atmosphere than they return to it by expiration.

4. *Carbonic Acid.* (CO_2)

This gas exists in the lungs, the alimentary canal, the blood, and the urine,[2] it being in the two latter in a state of *solution.* The amount in the blood would, in its *gaseous* state, occupy from one-fifth to one-third of the space actually filled by the whole mass of blood. It is dissolved in both the serum of the blood and the corpuscles, there being more in arterial than in venous blood (*R. and V.*), as is the case with oxygen and nitrogen. Oxygen is, however, dissolved principally in the corpuscles, as has been seen. The greater amount of carbonic acid gas in the arterial blood confirms the idea that it is set free in the lungs from the carbonates in the blood by the action upon the latter of pneumonic acid. (*Robin and Verdeil.*) That it is originally formed, however, by the action of

[1] Carburetted and sulphuretted hydrogen are also included among the immediate principles by Robin and Verdeil. They are here omitted, since they are found only in the air-passages and the large intestine, and appear to be evolved in consequence of some abnormal chemical process. In the intestine the sulphuretted hydrogen is always in smaller quantity than the other gases. It is *formed* in the alimentary canal; but precisely how, is not ascertained. It is also disengaged from abscesses near a mucous membrane (*e. g.* near the anus), or by putrefaction of pus or of organized tissue. Abscesses on the limbs, under the deltoid, or in the kidneys, have also been known to disengage it.

[2] "All the tissues in the body contain a small quantity of dissolved gases, and carbonic acid can be detected in all the animal fluids, &c."—*Todd and Bowman*, p. 730, Am. ed.

oxygen upon the tissues and the calorific elements of the food, may be regarded as established; and to prevent an undue accumulation of it in the blood from these sources is the principal object of the aerating process.

5. *Protoxide of Hydrogen—Water.* (HO.)

Water enters into the composition of every fluid and every tissue, however solid (even enamel), in the body, uniting in true binary combination, and forming one of its essential constituent parts. It is, therefore, one of the most important of the immediate principles, and exists in far greater amount than all the rest together.

The cubical mass of the human body is calculated by Robin and Verdeil as varying from 62 to 70 litres[1] in the male, and from 46 to 53 in the female—equal in the former to a cube 16 to 16.4 inches on a side. Of the preceding quantity, at least 42 or 43 litres are water, which equals a cubic mass 14.4 to 15.2 inches on a side. Thus nearly three-fourths of the body is water. Burdach estimated the water at two-thirds of its weight. Of course the proportion is still greater in infancy and childhood.

A table is given by the authors just mentioned,[2] showing the proportional amount of water in each fluid, and in each tissue and organ, in the body. With the exception of enamel, dried cuticle, teeth, bones, tendons, and elastic tissue, there is no tissue which is not more than one-half water. Enamel is only $\frac{1}{500}$ water (*Senac*); the substance of the testis, $\frac{887}{1000}$ water. The human brain is $\frac{789}{1000}$ water. (*Denis.*) But no tissue or fluid in the body has *always precisely the same* amount of water, or of any other immediate principle. It varies constantly, though within narrow limits, from one-tenth to three-tenths, and the mean only is given in the table alluded to.

But the other immediate principles vary with the variations in the water. Hence the error of those who would find the cause of diseases in one tissue or fluid alone, or who would cure them by the administration of water alone, or of any other immediate principle exclusively.

In all the tissues and organs just mentioned, in which less than one-half is water, and in many cases where the water constitutes $\frac{77}{100}$ (muscle) to $\frac{85}{100}$ (cortical substance of calf's brain) of the whole,

[1] A litre is very nearly a quart in measure.

[2] Op. cit., pp. 115–118.

the water is in a *solid* state, and entirely different from any condition in which it is found in the mineral kingdom. Hence muscle has more consistence than blood, and the cortical substance of the brain more than synovia; though these two fluids have less water than the solids compared with them. This water is, therefore, in *chemical combination* in the tissues, and not interposed between their elements.

In the fluids the water is, of course, in a *fluid* state, and here holds solids in solution. In a single instance only—the halitus from the lungs—is the water in a *gaseous* state.

Mere solution is chemical combination, but the feeblest known. Water combining with a solid in less amount than sufficient to dissolve, is *fixed* in it, itself becoming solid; in increased quantity, it dissolves the other substance, that, on the other hand, becoming fluid. The *organic substances* (osteine, musculine, &c.) have the peculiar property of fixing an amount of water of far greater volume and weight than themselves, while they still remain, and also render the water *demi-solid.* Organs formed principally of these substances, however (and hence containing much water, as explained), alone *live* independently and on their own account—alone present the double vital phenomenon of composition and decomposition.

But it is not, however, merely pure water—the mere protoxide of hydrogen—that is fixed and solidified by albumen, gelatine, &c., but a *saline solution* instead. Hence they swell when immersed in pure water, since an additional amount of the latter is thus generally fixed.

The muscle of the calf contains more water than that of the ox; but an equal weight of human bone (separate from the marrow), whether from the infant or the adult, contains the same amount of it.

Tables are given of the diseases in which the blood contains an abnormal amount of water, whether in excess or diminution. Since, however, the blood is, in almost all cases, taken from the arm alone, while that of the vena portæ, of the hepatic veins, and of the renal veins, is different, and cannot be examined in man, we need further investigation in regard to the blood in these latter vessels, in case of diseased animals, that we may thus infer its condition in the same vessels in cases of disease in the human body.

Whence comes the water in the body?—for it both enters and leaves the body already formed, *i. e.* as protoxide of hydrogen. The water in the ovum and in the embryo during development is

obtained from the body of the mother, first by imbibition from the mucus of the Fallopian tube by the vitelline membrane, then by the villi of the chorion, and when these become vascular, after the development of the allantois, they derive it from the mother's blood till birth. Subsequently it enters the blood from the alimentary canal, having entered the latter with the food, or as a beverage; accidentally entering, also (as in bathing), by the skin. The aggregate amount of water consumed as drink by an adult male in a year is about 1,500 pounds. M. Barral finds that more water leaves the body than enters it, and maintains that the surplus is formed in the body by the combination with hydrogen of the oxygen in the inspired air, and the excess of oxygen over the hydrogen in our aliment.

Uses of Water in the Body.—It gives to organic substances their mechanical properties, to fluids their fluidity, to demi-solid substances their elasticity and particular consistence; and different properties to the hard parts—to cartilage its flexibility, to bone its tenacity. But in the last the water is more intimately united, and being once separated, will not unite again. Water gives to all parts the possibility of manifesting their chemical properties also, and hence that instability characteristic of organized tissues, and the constant acts of combination and decomposition. But it also, with these advantages, confers the liability to sudden changes in the blood, or in the organs, from putrid, purulent, or mephitic infections, facilitates the transmission of poisons, procures the aptitude to decomposition, and hence, in many cases, induces sudden death.[1]

The water makes its *exit* from the body by the kidneys and the skin, in the feces, and from the pulmonary mucous membrane. About 1,900 pounds escape annually through these outlets, the urine alone containing 900 pounds. The fact that 400 pounds more of water are excreted than are ingested as drink is accounted for, in part, by M. Barral, as already stated; while it must be recollected that our food, also, always contains more or less water.

SECOND DIVISION.

The Saline Principles—Salts. (19.)

The salts contained in each tissue are represented by the ashes resulting from its combustion pretty nearly, but not precisely, since

[1] Robin and Verdeil.

the carbonic acid of the carbonates is set free by too elevated a temperature, and then merely the base remains in the ashes. Salts enter into the composition of every organized tissue, though sometimes in the slightest degree.

The salts in the fluids and tissues are merely dissolved in water; on being dissolved, they then serve as solvents for other immediate principles—*e. g.* solutions of salts with alkaline bases (soda and potassa) in the serum of the blood, dissolve certain fatty principles there.

None of the salts combine with the principles of the second class (those formed by dis-assimilation) except common salt, which unites with urea, forming the chloro-sodate of urea. It is, indeed, in this combination with soda that urea exists in the blood, in the vitreous humor of the eye, and, in part, also, in the urine. (*R. and V.*)

Some of the salts, especially several of the phosphates, in connection with water, combine directly with some of the organic substances (third class), and thus result certain organized substances, or tissues. *E. g.* the phosphate of lime combines directly with the osteine in bone, to form the tissue of the latter.

Besides, the earthy salts especially, by their union with the organic substances, manifest a power in aid of assimilation; and common salt, the phosphates of lime and magnesia, and the neutral phosphate of soda, are found in every tissue and every fluid in the body. Hence the salts are indispensable in our food. They also aid in dis-assimilation by yielding their bases, while still forming a part of the tissues, to acids of organic origin, as the uric and hippuric. By these latter combinations, also, the animal heat is in part produced. Moreover, their presence with the principles of the second class alone enables several of the latter to combine with oxygen, and even to displace it from metallic oxides.

Liebig discovered, in respect to this class, that the phosphates and carbonates of soda may replace each other in the blood without detriment. Hence, if the food contains only phosphates, without carbonates—*e. g.* bread and meat—the blood contains no carbonates; if potatoes be added to the preceding, the blood contains some carbonates; and if the diet be of fruits alone, the blood acquires the character and the composition of that of the ox or sheep. The urine also contains alkaline phosphates in the first case, and alkaline carbonates in the latter.

The observations of Bence Jones, to the effect that, in chorea and

delirium tremens, the sulphates and urea are increased in the urine, while the phosphates are diminished, and that in encephalitis the phosphates and the sulphates are considerably increased, are explained by a reference to the chemical composition of the muscles and of the brain respectively, and to the substances resulting from their dis-assimilation.

1. *Chloride of Sodium, or Marine Salt.* (NaCl.)

Common salt is contained in every fluid and every solid in the body, except that it has not yet been found in enamel. The urine of those *in articulo-mortis* is almost entirely deprived of it. It is the most abundant of the principles of inorganic origin, and is found during the whole period of existence, even in the ovule.

Its whole amount in the body of the male is about 277.05 grs.
" " " female " 234.9 "

In human blood the marine salt amounts to 0.31 to 0.37 per cent., and bears to all the other salts taken together the proportion of 2.4 (even 3) to 1; and the proportion is very similar in the blood of other animals. Muscular tissue contains very little of it, and Braconnot found none at all in the heart of the ox. There is more of it in saliva, gastric juice, mucus, pus, and inflammatory exudations,(?) than in the blood. Indeed, it always abounds where cells are forming in fluids.

It exists in a liquid state in every part except the bones, teeth, and cartilages. It is always dissolved in water, and *never chemically combined* in any tissue with the peculiar *elements* of the latter. Thus, also, it is never found in the organism in an isolated state.

There is three or four times as much common salt in the blood as in the muscles, and still more in the urine than in the blood. The proportion in the urine, however, varies with the nature of the aliment; that in the blood does not. There is a large amount of chloride of potassium in the muscles; and this salt has very generally been confounded with the chloride of sodium in analyses of the different organs and tissues. The forms of the crystals found in the urine, of common salt, are represented by Figs. 1 and 2.

Fig. 1.

Chloride of sodium obtained by treating urate of soda with hydrochloric acid, and slowly evaporating.

The presence of common salt in the blood is a condition essential to the endosmosis from the alimentary canal into the blood, of ali-

mentary substances dissolved in water, and of the solution of albumen, and perhaps of the fatty principles. In connection with albumen, it prevents the solution of the blood-corpuscles in the serum. It is also a condition of the acts of assimilation and *dis*-assimilation; hence the suppression of it in food produces chlorosis (even in man), languor, weakness, and paleness, and even œdema. It produces a more abundant secretion both of saliva and of gastric fluid, and thus facilitates digestion. Hence it is needed most if the food be principally vegetable, or in case of herbivorous animals, since this kind of food contains very little of this salt.

Fig. 2.

Chloride of sodium from slow evaporation of healthy urine.

More marine salt than is actually required in the organism enters the stomach in the food and drink. The average daily amount consumed is, according to M. Barral, 4.75 grains in the food, and 109.2 grains added as condiment; more than this amount, however, being used in the latter way during winter. It leaves the body in the urine, the feces, the sweat, and mucus.

2. *Chloride of Potassium.* (KCl.)

This is found in milk, the muscles, the liver, cerebro-spinal fluid, the blood, nasal mucus, saliva, bile, gastric fluid, and the urine. It exists, also, in the fluid rejected in choleras, and in that of dropsies. In the preceding alone has it thus far been found. It constitutes from 0.4 to 1 part in 100 of muscle, and only .03 to 100 in human milk. In blood the quantity has not yet been specified.

It is always dissolved in water, like common salt. And since in human blood the phosphate of potassa is always accompanied by chloride of sodium, and these two salts may become mutually decomposed into chloride of potassium and phosphate of soda, the salt under consideration may thus be formed in the body, as well as be introduced in muscle or milk used as food.

3. *Fluoride of Calcium.* (CaFl.)

This is found only in bones and teeth (both the enamel and dentine). Marchand finds 1 per cent. of it in human bone; the quantity in human teeth has not been determined. Berzelius found in the ox 4 per cent. of this salt in the enamel, and 5 per cent. in the dentine. It is not known from what alimentary substances it is derived, how it leaves the body, nor the part it acts therein, except by reason of its hardness.[1]

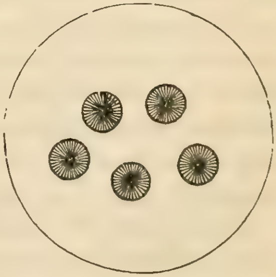
4. *Hydrochlorate* (*and Carbonate and Bicarbonate*) *of Ammonia.* (NH_3HCl.)

Nothing is known of the functions of these, and it is not demonstrated that the last two are immediate principles. The first exists in the tears, the saliva, and the urine. Whether formed in the body, or derived from the food, is unknown.

5. *Carbonate* (*and Bicarbonate*) *of Lime.* ($CaOCO_2$.)

The presence of the latter is only accidental in the human body. The carbonate of lime exists in bones, teeth, cartilages, and the blood. Otoconites are formed almost entirely of it. Traces are found in the ashes of the lungs. It is also found in the concretions (incorrectly called ossifications) of the muscles, arteries, valves of the heart, in false membranes, around fibrous tumors of the uterus, in the dura mater, and in the pineal body. Preputial, salivary, tonsillary, lachrymal, and certain pulmonary concretions, tubercles (cretaceous and the common form), and certain urinary, biliary, and arthritic calculi, contain this salt. In *all cases* it is combined with the phosphate of lime. It is sometimes also found in alkaline human urine. A rare form in the urine is shown by Fig. 3; it usually being an amorphous powder like the phosphate of lime. Landerer has also found it in the crystalline lens affected with cataract.

Fig. 3.



A rare form of carbonate of lime, found in alkaline urine.

This salt is found in most of the tissues and fluids in an amorphous state—*e. g.* in

[1] Dr. G. Wilson has demonstrated the existence of *fluorine* in the blood and in milk; and the fluoride of calcium exists in many mineral waters, and in plants growing in micaceous soils.

the pineal gland, on the plexus choroides, &c.; but otoconites are formed entirely of carbonate of lime, in crystals of the rhomboidal form, which is peculiar to it.

It is, doubtless, in a *solid* state in bones, teeth, and cartilage, and in the concretions before mentioned. It is certainly in a liquid state in the blood, but not in direct solution, since water very slightly dissolves it. The chloride of potassium and the carbonic acid there may aid in its solution, since both the former and also a fluid containing the latter acid dissolve it in a slight degree. In bone and cartilage the carbonate is doubtless united with the phosphate of lime before being combined (in company with it) with the organic bases (osteine and cartilageine) to form the fundamental organized substance of these two tissues. It is derived, in the organism, from spring water holding carbonic acid in solution, and also from the other salts of lime in the food.

Finally, much of the carbonate of lime found by calcination of tissues, &c., whence it is derived, may be formed by this process itself; since all the salts of lime which have a combustible acid (*e. g.* the lactic) are thus converted into the carbonate of lime.

6. *Carbonate and Bicarbonate of Soda.* ($NaO.CO_2$ & $NaO.2CO_2 + HO$.)

The first of these salts is found in the blood, feces, saliva; in the urine, when alkaline, without being ammoniacal; and in osteo-sarcoma. Valentin also found about one-third of one per cent. of it in the compact tissue of healthy bone. It is always, in the organism, dissolved in water, and therefore liquid or solid, as may be the case with the water itself. In blood it constitutes 0.1628 per cent., and in feces .08 per cent. To it is due the alkaline reaction of the blood, the saliva, and the cerebro-spinal fluid. It is combined with, and dissolves, the albumen of the blood; and even prevents the fibrin from coagulating, if the blood drawn from a vein falls into a vessel containing a solution of this salt. It maintains the elasticity and the firmness of the blood-globules, conditions without which hæmatosis cannot be secured. (*Robin and Verdeil.*)

A very little of this salt is derived from water and food; it is almost wholly formed in the body. The malates, citrates, tartrates, and lactates of soda and of potassa, contained in fruits taken as food, are all converted into the carbonate of these two salts respectively, and thus appear in the urine. The hydrogen lost by these acids, on being converted into the carbonic, is said to have been

withdrawn by combination with the atmospheric oxygen, to form water and produce animal heat; a proposition, however, which admits of doubt. The salt leaves the body in the urine, and a portion is also decomposed in the lungs, by the pneumic acid, into the pneumate of soda.

The *bicarbonate of soda* exists nowhere else than in the blood, and there its existence is very probable, rather than demonstrated. It is formed by the action of the carbonic acid in the blood upon the carbonate of soda. Its function is too nearly identical with that of the latter salt to need further notice here.

7. *Carbonate (and Bicarbonate) of Potassa.* ($KOCO_2$.)

The latter of these two salts is found in the urine of the herbivora, but not in the human body at all.

The *carbonate of potassa* exists in the blood of the herbivora, and of man and the dog, when they consume vegetable food. It does not, however, in the former, equal more than one-third or one-half of the carbonate of soda. It is formed, like the latter salt, from the malate, citrate, tartrate, lactate, &c., of potassa. Its function appears to be very similar to that of carbonate of soda.

8. *Sulphate of Soda.* ($NaOSO_3+10HO$.)

This principle exists in very small quantity in the body, but in almost every part and fluid, except the milk, bile, and gastric fluid. It may be found in milk when administered medicinally. Poggiale found 0.44 in 1,000 of human blood. It everywhere exists in a fluid state, dissolved in water, and conduces to preserve the elasticity of the blood-corpuscles, and to dissolve and keep in a liquid state the fibrin of the blood. It is derived, probably, from food and drink, and is evacuated in the urine.

This sulphate, and that of potassa, increase in the urine in inflammatory diseases, while both diminish in chlorosis and chronic maladies.

9. *Sulphate of Potassa and of Lime.* ($KOSO_3$ and $CaOSO_3$.)

The first of these is found wherever the sulphate of soda is, they being both dissolved in water, and mixed. Simon found 3 parts in 1,000 of urine. Its functions appear to be like those of the preceding salt.

The *sulphate of lime* is said to exist in the feces, in blood, and in

rachitic bones; but this is not yet certain. It is probably held in solution by the alkaline salts, already described. It is obtained from the water drunk. It is, perhaps, evacuated in small quantity in the urine; or is decomposed into some other salt of lime, and one of the sulphates just mentioned.

10. *Subphosphate or Basic Phosphate of Lime.*
(*Phosphate of Lime of the Bones*—$8CaO.3PO_5$.)[1]

The ashes of every tissue and fluid in the body of man and the mammiferæ contain this salt, while some of them have it for their principal constituent, so far as the mass is concerned. It consists of eight parts of the base combined with three parts of the acid. All calcareous deposits, as well as many urinary calculi, and phosphatic gravel, contain this salt. We have seen that in all cases this exists where the carbonate of lime does. It is the phosphate of lime which forms most of the calculi around foreign bodies introduced into the bladder, and those of the prepuce, and which is deposited on instruments left for a time in the bladder. It forms, often by itself, or with the ammonio-magnesian phosphates, the urinary sand; and prostatic calculi are formed of it alone. Uterine and vaginal concretions consist of this, with a little animal matter around some nucleus introduced from without. A calculus of this salt is shown by Fig. 4.

Fig. 4.

Phosphate of lime calculus, from the bladder.

The quantity of phosphate of lime varies in different parts. In bones there is 48 to 59, and in enamel even 88½, per cent.; in dry muscular fibre, .93 to 1 per cent.; in coagulated albumen (from the blood), 1.8 per cent.; and in fibrine (from venous blood), .69 per cent. It is also a constituent of caseine, globuline, and cartilageine; and of osteine in the white fibrous tissue, as well as in bone. In the ashes of urine are 2.57 per cent., and of solid feces 12.78 per cent. But the more a part is submitted to mechanical influences, the more phosphate of lime is deposited. Thus there is more in the bones of the lower than the upper extremities (in the same weight), and less than in either in the more passive ribs. The eburnation of bone is generally said to be an illustration of the same principle; though Lehmann found less than the normal amount of this salt in this condition. But when this

[1] Heintz finds the formula to be 3CaO,PO.

salt increases in the various bones, the others, except the phosphate of magnesia, diminish in proportion, and *vice versa;* the proportion of the principles of mineral origin remaining constantly the same at all periods of life, and both in the compact and the cancellated tissue. The salt just excepted, however, increases or diminishes with the increase or diminution of the phosphate of lime. (*R. and V.*)

This salt is in a *solid* state in bone, teeth, nails, and hair. Though insoluble in water, it is in a liquid state in the blood and all the other animal fluids, whether in its free state or combined with albuminous matters. When free, it is in solution by the aid of the free carbonic acid in the blood, of the bicarbonates, or by the chloride of sodium.

In bone it is combined with their peculiar organic substance (osteine), and doubtless with the other earthy salts. It is also combined with albumen and fibrine in the blood, as has been seen. In the urine it is held in solution by the acid phosphate of lime and of soda, and the other salts of these two bases; also by the carbonic acid in the urine. Its appearance as a urinary deposit is shown by Fig. 5.

Fig. 5.

Phosphate of lime in amorphous powder. The *rosettes* are the triple phosphate.

This principle gives to several tissues their physical properties of resistance and solidity, upon which their uses principally depend. This is most apparent in the osseous tissue. Liebig also ascribes to it the insolubility of certain tissues, as the muscular and the areolar.

It is derived from milk and other animal, and still more from vegetable, diet. The phosphate of lime of bones—*i. e.* the basic phosphate—exists in nature. It is evacuated in the urine. That in the feces is the overplus in the aliment which had not left the alimentary canal by absorption. A part is, however, changed into the acid phosphate of lime, and then aids in the decomposition of the tissues.

The *acid phosphate* or *biphosphate* of lime exists in urine (and in gastric juice?), and is formed, probably, from the basic phosphate.

11. *The Phosphate of Magnesia.* ($MgOPO_5$.)

This is found in all the tissues and fluids in the bodies of the mammiferæ, but in all cases in small quantity. It is more abundant in muscle, however, than the phosphate of lime.

It is found, in a crystallized form, in the pus of abscesses of different organs, in the serosity of ovarian and other cysts, in that of the pus of the pleura and peritoneum, and on the surface of carious and necrosed bones. Ovarian calculi are sometimes composed mainly of it, and a small quantity, at least, exists in all urinary calculi.

In human bone it constitutes 1.16 per cent.; in that of the herbivora it is more abundant (2.05 per cent. in the ox). In the varying physiological and pathological conditions it increases or diminishes with the phosphate of lime. Of enamel it constitutes 1.5 per cent.; of dentine, 1 per cent.; of muscle, .023 per cent. Cartilage contains a large amount—even 6.9 per cent.; and blood, .137 per cent. Human milk contains .05 per cent.

In bone, nails, and teeth it is probably in a solid state, and combined (as is always the case) with the phosphate of lime. Though slightly soluble, it is doubtless directly dissolved in water. In bone, &c., these two salts, first united together, combine with the plasma to form the organic principle, or osteine.

It is obtained, in the organism, from vegetable food; carnivorous animals deriving it from the bones of the herbivora. It is excreted principally in the urine; the feces also containing any amount not absorbed from the food, as well as that contained in the intestinal and pancreatic fluids. The formation in the organism of ammonia causes a part of this salt to pass into the state of ammonio-magnesian phosphate—as in the feces, in cases of typhus and dysentery. The function of the phosphate of magnesia in aid of endosmosis, and of assimilation and *dis*-assimilation, may be associated with that of phosphate of lime.

12. *Ammonio-Magnesian Phosphate.* ($MgO.NHO_4.HO.PO_5$.)

This is formed, as just explained, in the feces in disease, and in the urine after standing twenty-four hours or less; and sometimes when first excreted, if the latter is alkaline. It may form in any alkaline fluid containing the phosphate of magnesia. It is found in vesical calculi, gravel, and sand, and still oftener in renal calculi; and in intestinal, salivary, uterine, and biliary calculi. In all calculi it is habitually united to the phosphate of lime. It exists in the fluid form only in acid urine, being but slightly soluble in warm water and in solutions of other salts. A prolonged use of phosphate of magnesia (or mineral water containing it), has produced a vesical calculus, and in one instance even in two weeks.

It escapes from the body in the fluid (or feces) in which it is formed. For the various forms of its crystals, as found in the urine, consult Figs. 6 to 10.

Fig. 6.

Crystals of ammonio-magnesian (triple) phosphate, with mucous corpuscles, from catarrh of the bladder.

Fig. 7.

Stellate crystals of triple phosphate.

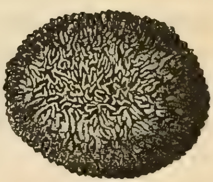
Fig. 8.

Foliaceous crystals of triple phosphate

Fig. 9.

Rosettes of triple phosphate.

Fig. 10.



Calculus of triple phosphate.

13. *The Neutral and Acid Phosphates of Soda.* ($NaO.2HO.PO_5+2HO.$)

The *neutral* phosphate is found in all the fluids and solids in the body. Urine normally contains both it and the acid phosphate, the former constituting 2.41 parts in 1,000. (*Simon.*) In cartilage it constitutes .92, and in woman's milk .04 per 1,000. It is always, in the body, in a state of solution in water; and this solution becomes a solvent of the insoluble phosphates and the nitrogenized substances. Thus it has properties analogous to the sulphate of soda. It may also replace the carbonate of soda in the blood, and does so in case of a substitution of animal for vegetable food.

It escapes in the urine and the feces, but in the former is con-

verted previously into the acid phosphate, or into the forms of phosphate of lime, of magnesia, or the ammonio-magnesian phosphate.

The *acid phosphate of soda* has hitherto been found only in the urine. We have seen how it may be formed from the neutral phosphate; the basic phosphate may also exist in the economy, and be converted by the union of carbonic acid into the neutral phosphate and carbonate of soda. The acidity of the urine is probably due to this salt. There is no *free* acid in fresh urine, except the uric, and this in very small quantity. The constantly changing reactions of this secretion are owing to the instability of the phosphate of soda. (*Robin and Verdeil.*)

14. *The Phosphate of Potassa.* ($KOPO_5$.)

This very much resembles, in all its relations, the salts just mentioned. Like the chloride of potassium, it is unfavorable to the exchange of oxygen and carbonic acid, since it destroys the consistence and elasticity of the blood-corpuscles, and, like it, is also much more abundant in the muscles than in the blood. Precisely the reverse is true of the phosphate of soda. In the muscles of the calf it is more than four times as abundant as all the other phosphates taken together. (*Robin and Verdeil.*) It is derived from vegetable aliments mainly. It has not been found in the urine; but, as, if meeting the chloride of sodium, the phosphate of soda and the chloride of potassium will be formed, it probably leaves the body in the form of these two salts.

15. *Carbonate of Magnesia.* ($MgOCO_2$.)

This salt exists rarely in the bones and in concretions, and is therefore included by Lehmann among the accidental mineral constituents of the body. It is often quite abundant in the urine of herbivorous animals.

CLASS SECOND.

IMMEDIATE PRINCIPLES OF ORGANIC ORIGIN, FORMED WITHIN THE BODY BY DIS-ASSIMILATION.

The principles of this class are sometimes termed "secondary organic compounds." They all have a definite chemical composition, are formed within organized bodies, vegetable and animal, and exist only in them. Being, however, formed (except the fatty prin-

ciples, as hereafter explained) by dis-assimilation, they constitute a part of the organized substance of the body only in an accessory manner, and not as original constituents of the tissues. Hence they are rejected from the body (except fat) almost as soon as formed, mostly in the bile and urine.[1] Their accumulation, indeed, is injurious, and, as in the case of urea and others, may prove fatal. Even fat, accumulating in the epithelial cells of the kidney or the liver, and in other cases of fatty degeneration, produces death. Very corpulent persons do not attain to an advanced age.

These principles (except the fatty, so far as they enter into the formation of adipose tissue) are not alimentary, not *assimilable.* Only the first and the third classes are so. Hence our food must contain these last, while it does not contain the principles under consideration. The fatty compounds, however, are required in the food for the development of adipose tissue; and sugar is usually taken in the food, though it may be formed in the body from starch, in case none is thus taken. But no tissue is nourished by it. In any tissue, therefore, except the adipose, in which these principles are found (as lactic acid, creatine, &c., in muscle), they are the result of the waste of the tissue itself.

Though so numerous (forty-two in all), the principles of the second class constitute a much smaller part of the body than those of the other two classes, since they generally exist in small quantities. Indeed, about *two-thirds* of them all are contained in the blood, and the urine is next in order in this respect. The bile contains several, also, which the urine does not.

All these compounds are in the *liquid* state in the body, except (sometimes) stearine and margarine; and perhaps the cholesterine of the brain. Some of them may, however, accidentally become solid, and form concretions, as uric acid, cystine, &c. Generally they are liquid by direct solution in water. Stearine and margarine, however, when liquid, are dissolved in oleine.

But nine simple elements are found in this class—sodium, potassium, calcium, magnesium, sulphur, carbon, oxygen, hydrogen, and nitrogen.

Preparatory to their exit from the body, these principles generally pass into the state of carbonates, and then of carbonic acid; or are rejected in the urine, either unchanged or after isomeric cata-

[1] This class, therefore, includes all the "urinary deposits," except the organized (as mucus, pus, and blood), and some of the salts just mentioned.

lysis. Some of them, however, are previously converted into lactic, uric, hippuric, or pneumic acid.

Since the tissues are formed mainly from the immediate principles of the third class, and those of the second class result from the *waste* of the tissues, it follows that the last-mentioned principles represent the amount of chemical elements of the third class which have ceased to be a part of the living organism. Hence, though very important to the physiologist, they need not occupy much space in a work on histology. The most important alone will, therefore, be particularly mentioned, and these as briefly as possible.

FIRST DIVISION.

Acid or Saline Immediate Principles of Organic Origin.

For the twenty-three compounds in this division, the reader is referred to the table, page 40. They are found in a notable quantity only in the excrementitious fluids, or in the urine alone, or in morbid products, except the inosate of potassa and the lactic and pneumic acids. Only these two acids, together with the uric and hippuric, and the oxalate of lime, will be here described.[1]

1. *Lactic Acid.* ($C_6H_5O_5.HO.$)

In its most concentrated state, lactic acid is a colorless, inodorous, thick, syrupy fluid, not solidifiable by the most intense cold. It exists in sour milk, resulting from the fermentation of its sugar. In the human body it is always found in the urine when the oxalate of lime is, and while one is living on a strictly animal diet; as it is in *all* circumstances in the urine of carnivorous animals. It is also abundant in the "muscular juice;" so much so, indeed, as to be more than sufficient, Liebig asserts, to saturate the alkali of all the alkaline fluids in the body. Lehmann has also found that lactic acid and the lactates exist in the human gastric juice and in the small intestines.

Origin.—The lactic acid in the stomach and small intestines proceeds partly from the gastric fluid, and partly from the starch and sugar in the food, by fermentation. It enters the urine, of course, from the blood; and the latter from the alimentary canal on the one hand, and from the muscular juice on the other.

[1] The last four salts of soda in this class (see the table), are peculiar to the bile.

Uses.—Lactic acid in the gastric juice (with the hydrochloric) is essential to the digestion of the nitrogenized elements of our food. Moreover, as the alkaline *lactates* are absorbed into the blood, they undergo rapid combustion (being thus converted into alkaline carbonates), and thus become the most efficient supporters of animal heat. The lactic acid in the muscular juice is doubtless a resultant of the use and *dis*-assimilation of the muscular tissue. Hence, as Berzelius asserted, it increases in proportion to the extent to which they have been exercised. Liebig's hypothesis, that an electric tension influencing the function of the muscles is established by the acid muscular juice and the alkaline blood in the capillaries, is simply ingenious.

The *lactates* of soda, potassa, and lime are also among the immediate principles of this class.

2. *Uric Acid.* ($C_9HN_2O_2.HO.$)

Uric acid always constitutes about 1 part in 1,000 of the urine of healthy men. It is usually far less abundant in carnivorous animals.

Fig. 11.

Uric acid crystals—artificial.

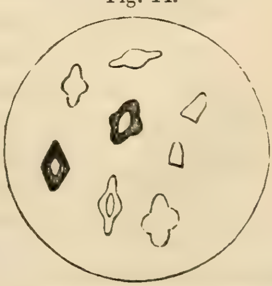
Fig. 12.

Uric acid—rhombs.

Fig. 13.

Uric acid—thicker rhombs.

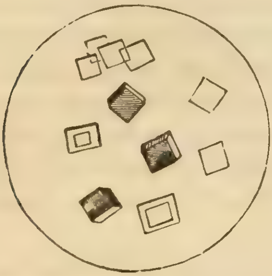
Fig. 14.



Uric acid—modified rhombs.

Its crystals are usually tinged with a yellowish hue by the coloring matter of the urine, and their various forms are represented by Figs. 11 to 19.

Fig. 15.



Uric acid—rhombs replaced by square form.

Fig. 16.

Uric acid—hour-glass crystals.

More uric acid is found in the urine during disturbed digestion, the urea being at the same time diminished. (*Lehmann.*) It is in-

Fig. 17.

Uric acid from urine.

Fig. 18.

Uric acid as sometimes found crystallized on a hair.

creased by any obstruction of the circulation producing deficient aeration of the blood; hence it increases during fever, in heart diseases, and enlargements of the liver; also very much in acute articular rheumatism. It diminishes, however, in gout.

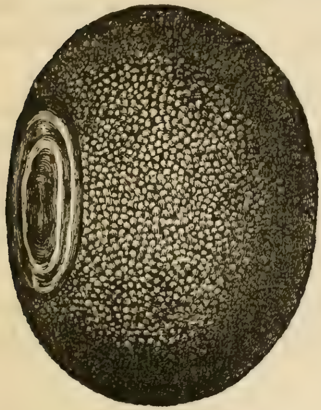
Fig. 19.

Uric acid crystallized on a fibrinous cast of a uriniferous tube.

In the urine, when discharged, it normally exists in combination with soda, and is found in its *free* state an hour or more afterwards. In some pathological states, however, and in cases especially of uric acid calculus (Figs. 20 and 21), it may be

found *free* in urine just discharged. It often constitutes the *nucleus* of the various forms of urinary calculi. (See "Urinary Concretions," Part II.)

Fig. 20.



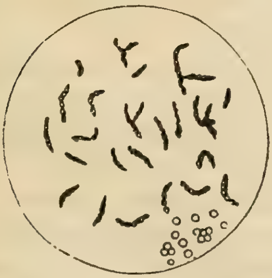
Uric acid calculus.

Fig. 21.

Uric acid calculus, showing internal concentric layers.

It is demonstrated that the urinary deposit described by Dr. Golding Bird as the urate of ammonia is the urate of soda. (Fig.

Fig. 22.



Urate of soda.

Fig. 23.

Urate of soda calculus.

22.) This salt normally exists in the urine, forming, when abundant, the "lateritious sediment," or the "amorphous yellow and impalpable sediment" (*Prout*) so common in febrile states. It also forms calculi (Fig. 23), and concretions in the joints. Indeed, the urate of ammonia (Fig. 24), very seldom occurs as a urinary deposit. (*Lehmann.*)

Fig. 24.

Urate of ammonia.

Uric acid also exists in the blood, the precise amount being not yet determined. It is, however, always increased in it in acute gout, and often in Bright's disease. It is not increased in acute rheumatism. From .004 to .0175 per cent. has been found in the blood of gouty patients. (*Garrod.*)

Origin.—Though uric acid is doubtless a result of waste of the tissues, it is not certain from what substance nor in what locality it is first formed. It appears to stand "one degree higher in the scale of the descending metamorphosis of matter than urea" (*Lehmann*)—*i. e.* it is converted into urea (and oxalic acid) by a partial oxidation. Hence, when aeration, and consequently oxygenation, is imperfect, more uric acid and oxalate of lime, and less urea, appear in the urine.

3. *Hippuric Acid.* ($C_{18}H_8NO_5.HO$.)

Hippuric (or uro-benzoic) acid is present in the urine during the use of a vegetable or a mixed diet. It occurs in large quantity in acid *febrile* urine, whatever the variety of febrile excitement, and in diabetic urine. (Fig. 25.)

Fig. 25.

Crystals of hippuric acid from human urine.

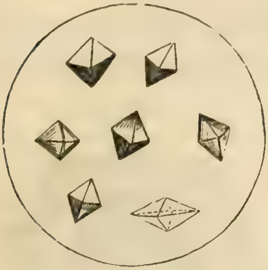
The hippuric has no ascertained relationship to the uric acid, nor is any thing certainly known of its origin. It is doubtless formed from the effete tissues, and has no special use in the organism. The hippurate of lime, soda, and potassa are also immediate principles.

4. *Oxalate of Lime.* ($CaO.C_2O_3$.)

This salt is frequently present in very small amount in normal urine; much increased, it indicates a pathological condition. The forms of its crystals are indicated by Figs. 26 to 29.

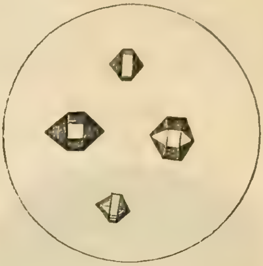
The dumb-bell crystals of oxalate of lime, so called, are probably the *oxaluret* of lime—Figs. 30 and 31. (*Bird.*)

Fig. 26.



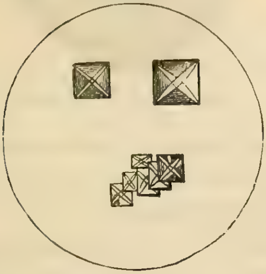
Octohedral crystals of oxalate of lime.

Fig. 27.



Oxalate of lime.

Fig. 28.

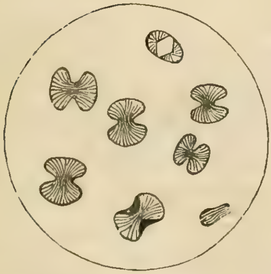


Oxalate of lime.

Fig. 29.

Oxalate of lime—octohedral crystals, *dried.*

Fig. 30.



Oxaluret of lime—dumb-bell crystals.

Fig. 31.

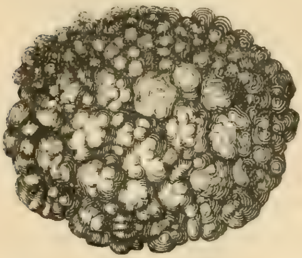
Oxaluret of lime—dumb-bell crystals.

The oxalate of lime increases in the urine after the use of vegetable food; and of beer which contains much carbonic acid gas, and the alkaline bicarbonates and vegetable acid salts. It often appears in the urine of pregnant women, and very constantly on the mucous membrane of the pregnant uterus. Lehmann finds that it increases

if the aerating process is in any way disturbed, and is common in pulmonary emphysema and chronic bronchial catarrh, and in convalescence from severe diseases—as typhus. It is always accompanied in the urine by lactic acid.

The *mulberry calculus* (Figs. 32 and 33) consists mostly of the oxalate of lime, and the latter enters in small quantity into almost

Fig. 32.



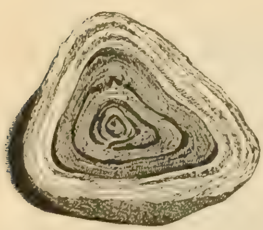
Oxalate of lime (mulberry) calculus.

Fig. 33.

Section of mulberry calculus.

all the varieties of calculi. It often forms alternate layers with uric acid (Fig. 34), a fact disproving the notion of the "uric acid diathesis."

Fig. 34.



Alternating calculus of oxalate of lime and uric acid.

In some cases of gout, the oxalate of lime exists in the blood. (*Garrod.*)

Origin.—Oxalic acid (C_2O_3) in the organism is normally converted into carbonic acid by oxidation—C_2O_3 becoming C_2O_4, or $2(CO_2)$. Any cause preventing this oxidation, therefore, causes an accumulation of oxalic acid, which, combining with lime, forms the salt under consideration. Oxalate of lime, therefore, proceeds—1. From the oxalate in vegetable food. 2. It accumulates if there be an excess of carbonic acid gas in the organism (as from beer, &c.). 3. Impeded aeration, producing diminished oxidation, may increase it; and hence debility of the nervous system may do so indirectly, by diminishing the respiratory movements. 4. Finally, oxalic acid may be produced by the oxidation of uric acid and several other substances in the organism; and hence diminished oxidation may produce more uric acid, and less oxalate of lime, so far as this source of the latter is concerned,

and *vice versa*. Hence, also, alternate layers of these two substances may be found in the same calculus, and the idea of the "oxalic diathesis" must, moreover, be regarded as a fiction.

5. *Pneumic Acid.*

Pneumic acid was discovered by Verdeil in 1851. It exists in the organized substance of the parenchyma of the lung, and at all ages of life. It has the same relation to the lungs that creatine has to muscle, being a result, probably, of their metamorphosis. It decomposes the carbonates in the blood, and thus sets free their carbonic acid, which accounts for its greater proportional amount in arterial than in venous blood (p. 44).

The pneumate of soda is also found in the lungs, and in the blood in them; but it subsequently disappears, not being found in any of the secretions.

SECOND DIVISION.

Neutral Nitrogenized Immediate Principles. (4.)

1. *Creatine.* ($C_8H_9N_3O_4$.)

Creatine forms transparent and very brilliant crystals (Fig. 35), and is found in muscular tissue (both the striated and the smooth fibre), in the blood, and in the urine. Lean meat contains more than fat meat, and the heart most of all. It constitutes about .067 per cent. of human muscle. (*Schlossberger.*) The flesh of fowls contains the largest quantity; that of fresh water fishes the smallest. It is always in a liquid state, dissolved in water.

Fig. 35.

Creatine crystallized from hot water.

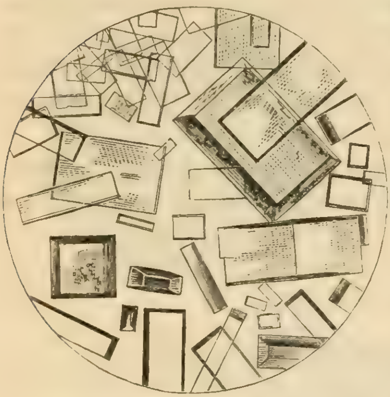
Origin.—Creatine in the muscular tissue is a constituent of the "muscular juice," hereafter to be described; but, from the readiness with which it is decomposed into creatinine and urea, there is no reasonable doubt that it is derived from the decomposition of the muscular tissue, and is de-

composed into these and similar substances in the living body, and thus expelled in the urine.

2. *Creatinine.* ($C_8H_7N_3O_2$.)

The crystals of creatinine are shown by Fig. 36. It is found only in the muscles and the urine, and always in company with creatine. The liquor amnii also *probably* contains it. (*Scherer.*) In the muscles it is far less abundant than creatine; in the urine it is far more so.

Fig. 36.



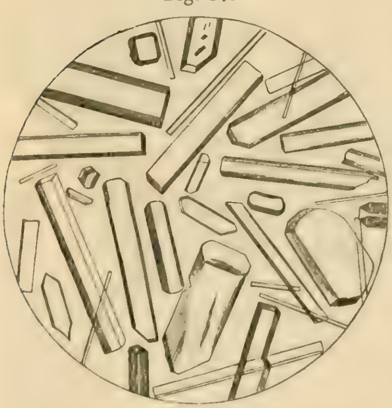
Creatinine crystallized from hot water.

Origin.—Creatinine is pretty certainly produced in the organism from creatine, being one degree lower than the latter in the descending metamorphosis of the tissues. It differs from creatine merely in containing two equivalents less of water, or is creatine minus 2(HO).

3. *Urea.* ($C_2H_4N_2O_2$.)

Urea is the most highly nitrogenized compound in the body. It crystallizes, if slowly, in flat, colorless, four-sided prisms (Fig. 37); if rapidly, in white, silky, glistening needles. It is found in the urine, the blood, and the vitreous and aqueous humors of the eye. It exists in combination with common salt (*i. e.* as chloro-sodate of urea), in the blood and the vitreous humor, and partly so, also, in the urine. (*Robin and Verdeil.*) Urea does not exist in the muscular juice. (*Grohé.*) It sometimes exists in milk (*Rees*), and very often in dropsical transudations. In Bright's disease it is found in all the serous fluids, and sometimes in the saliva.

Fig. 37.



Urea slowly crystallized from aqueous solution.

Urea normally constitutes about 13 parts in 1,000 of urine. (*Bird.*) The amount is increased by a nitrogenized diet, and by muscular exercises.

Origin.—It is decided that urea is formed in the blood, and it is doubtless formed *from* creatine, uric acid, and probably inosic acid also, by the action of the alkalies, and of free oxygen. (*Lehmann.*) And since creatine is produced by the waste of muscular tissue, strong muscular exercise increases the urea in the urine. Thus, also, in delirium tremens, and all states attended by intense muscular actions (convulsions, &c.), a similar increase occurs.

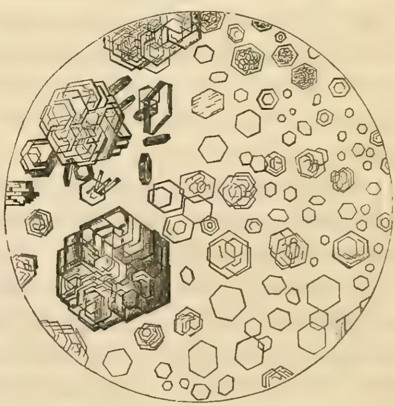
But urea probably also results from the decomposition of *any* tissue containing nitrogen, and not from that of the muscles alone. Moreover, if an excess of nitrogenized food is absorbed into the blood, it is excreted in the form of urea, this substance being the last and lowest step in the descending scale of the metamorphosis of the tissues, while the lactic, uric, and oxalic acids, creatine, and creatinine constitute the preceding grades. The idea of a "urea diathesis" is thus seen to be untenable.

4. *Cystine.* ($C_6H_6NO_4S_2$.)

Cystine occurs in colorless, transparent, hexagonal plates and prisms (Fig. 38), and only in the urine, and in pathological states. It is richer in sulphur (it constituting 25 per cent.) than any other organic substance, except taurine. It sometimes forms calculi.

Nothing is known of the conditions of the formation of cystine in the organism.

Fig. 38.



Cystine from urinary calculus, recrystallized from ammonia.

THIRD DIVISION.

Sugars, or Neutral Non-nitrogenized Immediate Principles.

But two kinds of sugar are found in animals—sugar of the liver, and sugar of milk. In vegetables there are several kinds; and grape sugar, or *glucose*, has the same composition as hepatic sugar.

Hence grape sugar, glucose, hepatic sugar, and diabetic sugar, are all synonymous terms, and are all expressed by the formula $C_{12}H_{14}O_{14}$. *Cane* sugar is $C_{12}H_{11}O_{11}$; and hence grape sugar is formed in the organism (though in small quantity) from the latter, by the addition of three atoms of water 3(HO).

Hepatic sugar (or diabetic) possesses great physiological importance, and is an immediate principle of the liver; and milk sugar is normally an element of that fluid. That either results, however, from the dis-assimilation of the organ producing it, is scarcely probable, though they are included in this class by Robin and Verdeil.

1. *Hepatic Sugar.* ($C_{12}H_{14}O_{14}$.)

Synonyms: **Diabetic Sugar; Grape Sugar; Glucose.**

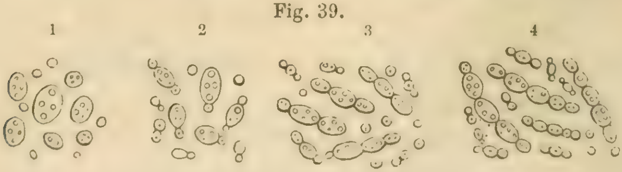
Hepatic sugar exists normally in the parenchyma of the liver, in the hepatic veins, and the portion between them and the heart, of the inferior vena cava, in the blood of the right heart and the pulmonary artery. During fasting, little or none is found in the pulmonary veins, the left heart, and the aorta and its branches; but during digestion it may be found in all these parts, in small amount, and sometimes in the veins generally also. A very little may be found in the vena portæ during digestion, but never at any other time, unless it be introduced in the food; though it will still be found in the hepatic veins. It never exists in bile, in the normal state.

It is found from the fourth or fifth month of intra-uterine life to the most advanced age. The urine of the fœtus in utero normally contains it, this fluid being at that epoch *normally diabetic.*

In *diabetes*, glucose exists in the urine, the kidney, the saliva, the serosity of the pericardium, and that produced by a blister, in the semen (of a dog), in matters vomited, and in the perspiration. Others add the feces also.[1] But none is found in the brain or spinal cord,

[1] The existence of the yeast fungus (torula cerevisiæ) in urine has been regarded as a proof of the presence and the fermentation of sugar. (Fig. 39.) Fungi of a

Fig. 39.



Torula cerevisiæ. Successive stages of cell-multiplication.

the pancreas, nor the spleen. There is much less sugar in reptiles than in birds and mammals, and none at all in the liver of the ray.

Glucose exists in a *fluid* state in the blood, dissolved directly in water. The contact of organic substances in that fluid rapidly (in twenty-four hours or less) converts it, by catalysis, into lactic acid. In the urine it normally combines with common salt, and thus loses the taste of sugar. In the liver of the higher animals the sweetish taste is owing to its presence. In some diseases no sugar at all is formed in the body for a short time before death. An excess of it is one of the signs of a deep general lesion.

Origin.—Normally, the grape sugar is formed in the liver, from the principles of the organism itself. The parenchyma, and the blood in the hepatic veins, contain it, though none exist in the food. (*Bernard.*) But cane sugar also, entering the vena portæ by endosmosis from the intestines, becomes grape sugar in the hepatic veins by fixing three equivalents of water. Perhaps the sugar of milk is converted in a similar manner. Glucose itself also exists in some articles of food (in cooked starchy substances, grapes, &c.), and then, of course, appears first in the blood of the vena portæ; though most of such substances pass merely into the state of dextrine ($C_{12}H_{10}O_{10}$), and which probably becomes glucose in the liver by assuming *four* equivalents of water.

The glucose actually *formed* in the liver (not derived from food, &c.) is formed in its *parenchyma*, and not in the blood,[1] since in animals bled to death it still remains in its substance. Anything increasing the activity of the circulation through the liver increases the quantity of sugar, and *vice versa.* Hence, probably, the fact that the condition of the nervous system modifies the amount of sugar (*Bernard*), since this modifies the circulation. Irritation of the medulla oblongata, at the origin of the pneumogastric nerve, was, therefore, found by Bernard to increase the quantity of sugar; and

precisely similar shape may, however, be developed in normal urine, after standing for some time at a high temperature, and sometimes even if the urine still preserves an acid reaction. But they have generally only about one-half the diameter of the yeast-cells, and are probably developed from the mucus. For an illustration of the forms of vegetation in urine, see Figs. 127 and 128.

[1] Dr. C. Hanfield Jones has recently maintained that the sugar is formed by the *cells* of the liver, while the bile is secreted by the *epithelial cells* of the hepatic ducts alone. Neither of these proportions, however, is probably correct. See "Liver," Chap. XIII.

irritation of its extremities in the lung, by inhalations of ether or chlorine, produces the same effect, by a reflex action to the liver. Hence we may infer that in diseases of the lungs or medulla oblongata, diabetes might occur.

The changes necessary to convert the cane sugar and the dextrine of the food into glucose in the liver have already been stated. Moreover, Bernard has shown that this change is effected by the pancreatic juice in the duodenum. But all thus formed passes from the vena portæ into the hepatic vein, while in the preceding circumstances it is formed by and in the substance of the liver itself.

The glucose disappears from the blood by being converted, catalytically, into *lactic acid* ($C_6H_5O_5.HO$), which decomposes the carbonates, and combines with their bases in the blood. But they are soon reconverted into carbonates, and in this form are evacuated in the urine. If there be an excess of sugar in the blood, it will pass off as such in the urine, and perhaps also appear in other secretions already specified.

2. *Sugar of Milk.* ($C_{24}H_{24}O_{24}$.)

Synonyms: Lactine; Lactose.

This is found only in milk, and in that of all the mammalia. It exists only from some point of time after puberty, continues only a few months at a time, and ceases a few months after the last pregnancy. In woman's milk it forms 3.2 to 6.4 per cent.; the colostrum containing even 7 per cent. It diminishes in quantity the further the date from the previous delivery; being 5.5 per cent. a few days after delivery, it had fallen to 4.6 per cent. five months from this time.

It becomes glucose (as does cane sugar) in the liver, and then is finally converted, as before explained, into lactic acid.[1] If this latter change occurs in the milk itself, it becomes acid spontaneously.

Origin.—The parenchyma of the mammary gland *fabricates* the lactine, as that of the liver does the glucose; from what elements is not precisely known. The longer the milk remains in the breast, the less sugar and other solid principles, and the more water, it contains. The kidneys and the lungs are merely *eliminators*, and not *fabricators*.

Taken into the stomach of the infant, the lactine may be con-

[1] Four atoms of lactic acid equal *one* of lactine.

verted into glucose by mere addition of water, or by the action of the pancreatic fluid in the duodenum. Or if not thus, this conversion occurs in the liver. Its subsequent disposal has already been explained.

FOURTH DIVISION.

Fatty Principles (Fatty Acids and Soaps).

All the immediate principles of this class exist in a *fluid* state, except that cholesterine, margarine, and perhaps stearine, are sometimes, in morbid conditions, found solid. They are also composed of carbon, hydrogen, and oxygen alone, and in definite proportions, and are found in both vegetable and animal organisms. There is, however, no proof that they are the result of *dis-assimilation*, though included in this class by Robin and Verdeil.

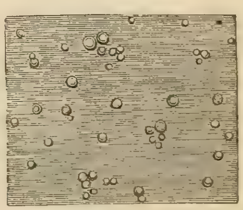
The fatty principles exist in the tissues and fluids of the human body in three entirely different conditions:—

1. Inclosed in cells, which constitute the fatty or adipose *tissue*. This will be described in connection with the other tissues.

2. They exist in chemical combination with other elements, and hence can be detected only by chemical analysis. This is the case with the fat in the organic matter of epithelium, nails, horn, and hair.

3. They form minute oil-drops, or "fat-globules," without any envelop, and in this form naturally enter into almost all the tissues, except teeth and bones,[1] and into many of the fluids. They are very minute, though of varying size, and possess a high refractive power. (Fig. 40.) Thus the fatty principles are completely isolated from all others, though they exist with others in the same tissue or fluid. These drops are, however, themselves always made up of several of the fatty principles united together, molecule to molecule; and the same is true of the fat in the cells of adipose tissue. The only exceptions are the fatty elements of the brain, cholesterine in the blood, and certain

Fig. 40.



Fat-globules.

[1] Bones inclose fat in their cavities, but here it is contained in cells.

fatty acids, each of which may be found in a state of isolation from other fatty elements.

Though several of the tissues contain the fat-globules under consideration, they are most abundant in the corpus luteum. They also abound in cancerous (encephaloid), atheromatous, and other morbid growths; and when they replace the normal tissues in organs, or become abnormally abundant in them, they produce the "fatty degeneration," or Stearosis, and in this way may produce fatal results. The organs most liable to this change will be specified in the chapter on "Adipose Tissue."

The fat-globules exist in the *fluids* in a state of suspension or emulsion. The smallest of all are those of the chyle. They are twice or thrice as large in the blood *during digestion*, and are still larger in milk, constituting the *cream*. Fat-globules also normally exist in urine, semen, prostatic fluid, saliva, nasal mucus, synovia, and bile, and in the serosity of the pleura, of the peritoneum, and that produced by a blister. Blood-serum contains fat even when mixed with other fluids (as urine), and pus also contains it in notable amount.

The fatty immediate principles exist in the ovum, and through life. In the adult they constitute about 5 per cent., or $\frac{1}{20}$ of the weight of the body. Of the entire brain, fat constitutes at least 10 per cent.; of the muscles, $1\frac{1}{2}$ to 4 per cent.; and of the blood, 0.14 to 0.33 per cent. The globules alone of the blood contain 0.331 per cent.; the serum alone, 0.175; and the fibrine (when dry), 2.6 per cent.

Origin.—The fatty principles in the body are mostly taken into the organism, already formed, in the food, and, being converted into an emulsion in the duodenum and jejunum by the action of the pancreatic fluid (*Bernard*), are then absorbed mainly by the lacteals, and enter the venous current from the thoracic duct. But it is also extremely probable that the fatty principles may be, to some extent, formed in the human organism; and Liebig's idea that they are formed in the *alimentary canal*, from the metamorphosis of certain nitrogenized elements in our food, is the most plausible. At least, the amount of fat in the *blood* does not vary much, whether the food contains very much fat, or is deficient in it (*Boussingault*); and both the amylaceous and the nitrogenized compounds in our food certainly afford the elements for the formation of the fatty principles. The fact sometimes cited to prove that carnivorous animals form fat within their own organisms—viz., that their milk contains fat—

proves nothing, since most of the tissues of the animals on which they prey also contain it.

It is also very certain that the human liver has the power to *form* fat directly, to some extent, as well as sugar (p. 71). It is not, however, probable that the adipose tissue is nourished by fat formed elsewhere in the organism, but that the fatty materials for its nutrition are contained in the food, or, in default thereof, may be elaborated by the fat-cells themselves out of the other elements brought to them in the blood. But that almost all the fatty principles in the body are, under all ordinary circumstances, introduced in the food, hardly admits of a reasonable doubt.

Of the fatty principles which enter the blood, a portion is appropriated to the nutrition of the adipose tissue, and others normally inclosing "fat-globules," and for the secretions which contain the latter; the remainder is burned up by combination with oxygen to maintain the animal heat, and leaves the body in the form of carbonic acid and water.

Though the fatty principles possess great physiological importance, only oleine, margarine, and stearine are especially important to the histologist. These, therefore, and cholesterine, will alone be here considered. "Seroline" has been shown by Lehmann to consist of the crystallizable parts of several fats blended together.

1. *Cholesterine.* ($C_{37}H_{32}O$.)

Cholesterine (or bile-fat) crystallizes in very thin rhombic tablets. (Fig. 41.) It is normally dissolved in the bile, and is found in the blood, bile, liver, brain, nerves, feces, cerumen, the crystalline lens, and in many pathological productions. Gall-stones are composed almost entirely of it.

Fig. 41.

Tablets of cholesterine.

The blood contains about .088 parts of cholesterine in 1,000. It increases in old age, and in most acute diseases; especially in inflammations, and in icterus. It also occurs in pus, and often in dropsical transudations, cretaceous tubercles, old echinococcus cysts, encysted tumors, de-

generated ovaries and testes, and carcinomatous growths. It has not, thus far, been found in the urine.

Cholesterine is found only in animals, and must be formed in the organism—by the liver, probably. It is not, however, known from what elements it is formed, nor what office it performs in the organism; nor how it makes its exit therefrom, except so far as it is contained in the feces. It is, however, to be regarded as an excrementitious product, and probably is a result of *dis-assimilation* of the liver itself.

2. *Oleine, Margarine, and Stearine.*

These three immediate principles are combined together to form the contents of the cells of adipose tissue, and the fat-globules in various tissues and fluids. Each of them is composed of a fatty acid in combination with a compound radical—the oxide of lipyl. (C_3H_2O.) From the latter glycerine is formed.

1. *Oleine* ($C_{39}H_{36}O_5$) is compounded of the oxide just mentioned and oleic acid. ($C_{36}H_{33}O_3.HO$.) It is, therefore, the oleate of the oxide of lipyl. When isolated, it maintains its fluidity at any temperature above zero of Fahrenheit, and in it are the margarine and stearine in the tissues, dissolved.

2. *Margarine* is a compound of margaric acid ($C_{34}H_{33}O_3.HO$) with the oxide of lipyl, or is a margarate of this oxide. It becomes solid at a temperature of 118° Fahr. It forms a much greater proportion of human fat than oleine.

3. *Stearine* exists in human fat, but in very small quantity. It is a compound of stearic acid ($C_{68}H_{66}O_5.2HO$) and the oxide of lipyl, and is the stearate of this oxide. Stearine does not exist in vegetables, but is the main constituent of all solid animal fats, as spermaceti, suet, and tallow.

Butter contains margarine and oleine, but no stearine. The last may, however, be formed in the organism from the other two principles. In a dog taking butter alone for sixty-eight days, the liver contained a large quantity of stearine, and very little if any oleine. (*Magendie.*) It will be seen that two equivalents of margarine precisely correspond to one of stearine, with the addition of one atom of oxygen. These three principles together will not, however, by themselves nourish an animal, while adipose *tissue* will do so for a time.

Soaps are formed by boiling either margarine or oleine with

potassa or soda. Some of the fatty principles are, however, not thus decomposed by alkalies, nor by the oxide of lead, and are, therefore, called *non-saponifiable* fats. Cholesterine and seroline are of this class.

It is probable that potassa decomposes fat in the body as well as out of it; hence the liquor potassæ is the most reliable remedy for excessive corpulence.[1]

Uses of the Fatty Principles in the Organism.—These have been generally stated on a previous page (p. 75). Certain further particulars should find a place here.

1. The use of fat in the adipose *tissue*, or rather of adipose tissue itself, will be specified further on.

2. The fat in the *blood* is partly appropriated to the nutrition of the adipose tissue, and partly appears in the form of "oil-drops" in the tissues and in several secretions (p. 75). A portion also enters into organic combination in the structure of the brain; and, finally, the overplus of the fat is burned up, and thus becomes a calorific material, being converted into carbonic acid gas and water, and thus leaving the body.

But it is also quite probable that the bile is formed, in part at least, from the fat in the blood. Lehmann, however, considers it doubtful if the cholesterine is derived from this source. But the blood of the vena portæ contains more fat than that of any other bloodvessel in the body; besides, it is of a darker brown color, contains more oleine, and is therefore more greasy than the fat in other veins. The fact that there is much less fat in the hepatic veins points to the inference that the bile is formed in part from that in the vena portæ; and this is confirmed by the fact—*first*, that the secretion of bile continues free during starvation, and while emaciation is progressing; *secondly*, that the blood contains more fat in icterus than in any other disease; and, *thirdly*, that a disease of the liver producing diminished secretion of bile also produces obesity, as that occurring in drunkards from nutmeg liver and other diseases of that organ. In acute diseases, also, emaciation first becomes manifest in connection with a free discharge of bile from the alimentary canal. (*Lehmann.*)

Lehmann expresses the opinion that fat also co-operates in the formation of the blood-pigment, or hæmatine.

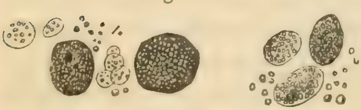
[1] See the chapter on "Adipose Tissue."

It is an interesting fact that in tuberculosis the saponified fats are far more diminished in the blood than in any other fluid. (*Becquerel and Rodier.*) Solid tubercle itself also contains but little fat; and it is not an unphilosophical idea that the principal predisposing cause of tuberculosis is this same diminution of fat in the blood, and that it is for this reason that fatty compounds—and, above all, cod-liver oil—are found so efficient to prevent or arrest it.

3. Why fat exists in some of the *secretions*—as semen, mucus, &c.—is not understood. Of pus, Guterbock found fat sometimes to constitute even 5· per cent.; about 3½ per cent. being contained in the corpuscles. But it follows that an excessive secretion of these fluids must produce emaciation, as results from profuse suppuration and from venereal excesses.

The fat in *milk* is essential to the development of the young mammal. It constitutes 2½ to 4 per cent. of woman's milk, and exists both within cells and in the form of oil-drops. In the colostrum it forms the peculiar granular cells, or "colostrum-corpuscles;" and which, being also seen in inflammatory exudations, in the sputa of chronic catarrh, in old apoplectic cysts, &c., have been termed "glomeruli" and "inflammation-globules." (Fig. 42.) Not a single primordial cell, indeed, can be formed in the embryo without fat as one of the elements of its composition. Hence plastic exudations, also, must always contain fat, and its entire absence would alone render an exudation non-plastic. In inflammatory exudations, fat is usually more abundant than in the liquor sanguinis.

Fig. 42.



Glomeruli and granulous cells; the darker ones being the glomeruli.

4. Fat is present in other tissues than the adipose, in the form of oil-drops, mainly for a mechanical purpose, it would seem; but when it becomes excessive in amount, a pathological state—*stearosis*—ensues.

5. The uses of fat in the *food* are, in great part, to be directly inferred from the preceding remarks; but it is also known that fat, in combination with the albuminous elements (albumen, caseine, fibrine, &c.) of our food, renders the latter more easy of digestion. (*Lehmann and Elsässer*). The presence of fat is also necessary to enable albuminous matters to act as ferments. (*Lehmann.*) Besides, fat is indispensable for the original development of all the tissues,

since all the nuclei of the primordial cells contain fat-granules. Cell-growth, therefore, bears some proportion to the amount of fat assimilated; and even pathological formations of rapid growth abound both in cells and in fat—*e. g.* encephaloid.

Remarks.—1. From the fact that so large an amount of fat—one-tenth part—enters into the composition of the brain, the general emaciation which ensues from long-continued intellectual effort may be explained; for fat is here so indispensable that the nervous centre will draw upon the other tissues and organs when its own supply is exhausted; and in cases of fatal emaciation, death always occurs before the fat is notably diminished in the brain and the spinal cord. The fact that excessive activity of the brain also produces an abundant deposit of phosphates in the urine, is explained by the *dis*-assimilation of the phosphorus which so abounds in that organ (p. 36), and which thus passes into phosphoric acid, and then unites with the alkaline and earthy bases.

2. Cod-liver *oil* is a kind of fat which, *first*, aids in the digestion of the albuminous elements of the food; and, *secondly*, is also found experimentally to be itself easily assimilated in parts requiring fat for their nutrition. It is, therefore, of great value in cases of actual or threatened emaciation, from *any* cause. Any effect of this substance, further than that of protecting the various organs from the impending loss of their fat, and thus maintaining the strength (by protecting the muscles, especially), is merely theoretical. In a word, it contributes to a more perfect nutrition in the two ways just explained, and thus, in case of prolonged disease, sustains the strength until perhaps the morbid process exhausts itself. Thus it acts in tuberculosis, it is believed, and thus alone. Being mere food, therefore, and not medicine, it should be given with other food, as a general rule, and not between the meals, as is often recommended. If it disagrees with the stomach, the addition of an alkali may remove this objection, it probably aiding the pancreatic fluid in converting the oil into an emulsion fit for absorption by the lacteals.

If it be inquired why other oils of similar composition are not equally valuable in cases in which this succeeds, it can only be replied that the fact has been demonstrated by direct experiment, and experimentation settles everything in therapeutics. But there is no better reason for adding the phosphate of lime to the cod-liver oil (a fashionable combination of late), than there is for the carbonate

of lime and other salts which have been spoken of as immediate principles; unless a diminished amount of the phosphate of lime is taken in the food, or the bones, especially, need an increased amount of it—as in rachitis and malacosteon.

Second Group.

CLASS THIRD.

ORGANIC SUBSTANCES, OR COAGULABLE PRINCIPLES.

The organic immediate principles constitute the greater part of the mass of the organism; those of the first class entering it in smaller, and those of the second in very small proportion. These are all nitrogenized compounds, or compounds of carbon, hydrogen, oxygen, *and nitrogen*, and all of neutral reaction.

It is, however, a peculiarity of this class of principles that they have *not a definite chemical composition*, as is the case with the other classes. It is, indeed, constantly varying, though within certain rather narrow limits, the variation rarely exceeding 1 per cent. in respect to either of the chemical elements entering into their composition. It follows, of course, that the combinations of these principles with other substances (as acids, alkalies, &c.) cannot be definite and uniform compounds; *e. g.* sulphate of copper and albumen being mixed, the salt is decomposed, and its two elements combine with the albumen; yet the result is neither sulphate of albumen, nor albuminate of copper, in definite proportions.[1] (*Robin and Verdeil.*)

If, therefore, albumen, fibrine, &c., are constantly varying in their own precise composition, much less is it true that these two substances are always identical in composition. And yet two analyses of them (*e. g.* of fibrine) may not be more nearly identical in their results than an analysis of the former as compared with one of the latter.

Most of the earthy salts—phosphates, carbonates, oxalates, silex, and the silicates—unite with these substances; hence, whenever concretions are formed by the former, a certain quantity of the organic substances is fixed and retained in them. This union is, however, more feeble than that with the metallic salts, and hence is

[1] Hence the difficulty of distinguishing these principles from each other by the reactions of mercury, tin, copper, &c.

constantly overcome and renewed in the act of assimilation and dis-assimilation. It is from the more intense union of the latter with organic matters that decomposition after death is prevented by some of them, since thus these matters are hardened and contracted. Thus, also, these salts become the *poisons* called metallic, as those of arsenic, mercury, &c.

Some of these principles (albumen, caseine, and fibrine) are in a *fluid* state in the human body; the rest are in a demi-solid or a solid state. All these may be reduced to a more solid state by evaporation of the water which forms a part of their chemical constitution, and which may be again recombined if they are plunged into this fluid. Meantime, however, the tissues containing these substances cease to perform their functions; and if too long dried, or too completely so, the readdition of water does not restore the lost power. Thus these are not solid substances in a state of solution, but the water is a part of their chemical constitution.

Coagulation is also merely *the passage of a liquid or semi-liquid substance into a solid state*, and not the return of a substance in solution to its primitive solid state; and the organic substances alone coagulate. When coagulated, they still retain their *water of constitution*, still united, molecule to molecule, in the organic matter, as before.

The *materials* for the formation of these principles arrive in the organism already formed in the food (*e. g.* albumen, fibrine, &c.), whether obtained from other animals or from vegetables; and which, undergoing digestion, affords the elements for their formation in the human body. But the *formation* occurs in the organism itself. It has been suggested that those principles existing in the blood, especially albumen and fibrine, may have been formed from the same in the food, from the occurrence of merely isomeric changes in the latter. This is, however, improbable, so far as the fibrine is concerned, as will appear in a subsequent part of this work.

Though these principles constitute a great part of the mass of the human body, the *weight* of other principles is, in certain organs, greater than of these; *e.g.* the phosphate of lime in bones and teeth, as compared with the osteine.

Of the organic principles, osteine and elasticine are not found early in embryonic life; and caseine, being an element of milk, is found only in the female, and after puberty.

It is probable that neither of these principles can be directly

transformed in the organism into another, except, perhaps, that the albuminose of the blood may be transformed into albumen. It appears, however, that either of the organic principles taken in our food, and subsequently changed by the digestive process, may afford the *materials* out of which the same, or perhaps several others of the organic substances, may be formed in the organism by the assimilative endowments of its respective parts and organs. Still less can any tissue once formed be directly transformed into another, as cartilage into bone, &c. Whenever this appears to be the case, the former tissue is, in fact, *replaced* by the latter.

All these substances are assimilable; *i. e.* they do not appear in the urine[1] if admitted into the blood from the alimentary canal or otherwise, in proper quantity, but disappear entirely from the blood, and become associated with the tissues. Even the organic substance of bone (osteine), so long as it is associated with the phosphate of lime, will sustain an animal. (*Magendie.*) The fluid obtained by prolonged boiling of bone is, however, not capable of sustaining animal life for a long time, for thus the osteine is converted into gelatine, which is not assimilated, but appears in the urine.

But none of these organic substances, taken alone, can long sustain life; the principles of the first and second classes must be added, as mere accessories, but, at the same time, indispensable. In muscle, for instance, the musculine is united, though feebly, with creatine and creatinine, besides the water and the salts. Nor can *any* principle alone (not even the organic substances) form a substance manifesting a single vital property. If the fibrine of the blood sometimes appears to do so, it is because the blood contains the principles of all three classes; for fibrine alone, though it may form a false membrane (falsely so called), can never become vascular.

Thus we must distinguish between the *organic* principles on the one hand, and the anatomical, or rather *histological*, elements of the organism on the other. The former have no proper *form*. The latter present the form of membrane, fibres, cells, &c., and are never constituted of a single substance alone. The simple cell or membrane contains principles of all the three kinds, water always existing in greater or less abundance, besides salts and other compounds.

[1] In diseased conditions of the kidneys, albumen may exist in the urine, as all are aware.

Chemistry alone, then, does not give a just idea of the organic substances; their examination is a part of anatomy. "It is not carbon, hydrogen, oxygen, and nitrogen which directly form the organized substance, but bodies composed of these, which act directly, and which naturally arrange themselves in three distinct classes." (*Robin and Verdeil.*)

The organic substances leave the body after *dis*-assimilation, in the form of lactic and uric acid, urea, carbonic acid, water, &c. Creatine may pass into creatinine, and subsequently into urea, and then appear in the urine, it being principally derived from the dis-assimilation of musculine. Albumen and gelatine may also pass into leucine, the gelatine being derived from the dis-assimilation of the osteine in bone and white fibrous tissue, as before stated.

Classification of the Organic Immediate Principles.

The organic substances are eighteen in number, the first two divisions of them constituting the "albuminous compounds." Albumen, caseine, and fibrine have recently been termed the "proteine compounds," since a compound called proteine, and represented by the formula $C_{36}H_{25}N_4O_{10}+2HO$ (*Mulder*), is obtainable from them all, and which has been assumed to be their compound radical.

Proteine does not, however, exist in nature. It is obtained only by the destructive decomposition of these substances, and, therefore, however convenient to the chemist, it has no interest in histology. Two oxides of proteine are said to exist in the blood—the binoxide and the tritoxide; the latter during inflammations more especially. What their relations to the tissues are, is, however, unknown.

Nor do we admit the "gelatinous compounds" hitherto described. Gelatine (or glutin) and chondrine do not exist naturally in the human body, but are formed from osteine and cartilageine respectively, by chemical agency, as will be explained in the description of these two organic substances.

FIRST DIVISION.

Those Naturally in a Fluid State.

Of these seven substances, pancreatine, mucosine, and ptyaline have no special importance in histology, but will be again alluded to in the part describing the fluids in the human body.

Pancreatine is found only in the pancreatic fluid.

Ptyaline is found only in saliva.

Mucosine is found in mucus. Three kinds, at least, may be specified; and Robin and Verdeil mention five. 1. From the mucous membrane of the nares and bronchial tubes, large intestine, and the interior of the uterus. 2. From the neck of the uterus. 3. In the urine.

The remaining four substances are, however, of paramount importance in histology, and will be particularly considered. They are albumen, caseine, albuminose, and fibrine; the first three of which may be termed the "nitrogenized histogenetic substances." (*Lehmann.*)

1. *Albumen.*

Albumen is found in the serum of the blood (seralbumen), in the chyle and lymph, in all the serous secretions, the liquor amnii, and the aqueous and vitreous humor of the eye. Of the blood it constitutes 63 to 70 parts in 1,000; of the chyle, 30 to 60; and of lymph, only 4.34 parts. It exists in the blood in connection with soda, which is supposed by some authors to keep it in its fluid state. The latter is, however, the natural state of this immediate principle. (*Robin and Verdeil.*)

Albumen coagulates at a temperature of 145° to 150° (Fahrenheit). If in very dilute solution, however, a boiling heat may be required to solidify it. It is also precipitated from a solution, in a solid form by the tannic, nitric, and all the mineral acids, except the phosphoric. The last, and all the vegetable acids, except the tannic, even dissolve solid albumen. With the former class of acids, and with metallic oxides, the albumen unites as a base, and forms a nitrate, tannate, &c., of albumen, though of varying composition.

But albumen also combines with alkalies and alkaline carbonates as an acid; these compounds (albuminate of soda, &c.) being soluble in water. The neutral albuminate of soda exists normally in the blood of the hepatic and splenic veins; the basic in all the other vessels.

With most of the metallic salts (acetate and other salts of lead, the salts of mercury, &c.) albumen forms *insoluble* compounds.

It is coagulated by the ferrocyanide of potassium, by alcohol, and by creasote. The last acts by catalysis.

Seralbumen contains 2 per cent. of phosphate of lime, besides alkaline and earthy sulphates and phosphates, and chloride of sodium. Ovalbumen is the form of albumen found in eggs. Of the

white of eggs it constitutes from 12.0 to 13.8 per cent. It differs slightly in chemical composition from seralbumen.

Albumen is said to exist in a solid form in the spinal cord, the brain, the nerves, and probably in several other organs also; but, since it is impossible to distinguish coagulated albumen from coagulated fibrine in the tissues, this assertion must be received with some reservations. It is impossible to decide whether it is coagulated albumen or coagulated fibrine that exists in tubercle and scirrhus. (*Lehmann.*) The phosphate of lime in the bones is generally said to be obtained from the albumen of the blood-serum.

As albumen has not a definite chemical composition, its compounds necessarily have not. It, however, combines in large proportional amount with the substances previously mentioned, the combining number of seralbumen being over 22,200. (*Mulder.*) That of soda is only 31.3. Seralbumen, however, differs in different persons. Sulphur and phosphorus are always found in connection with it.

Origin of Albumen in the Organism.—The albumen in all the tissues, and all the fluids (except chyle), is, of course, derived from the blood. Most of that in the blood (except what enters from the lymph and chyle) probably enters it in the form of *albuminose* from the alimentary canal; and it is not certain that it can, in entire default of the latter, be formed at all in the organism itself. Such a formation, to some extent, even from the non-nitrogenized elements of the food, is not, however, improbable.

The albuminose, from which the albumen in the blood is directly formed, is produced by the digestion (principally by the action of the pancreatic fluid), of either or all of the albuminous immediate principles in the food, or of either or all of the demi-solid organic substances next to be considered (musculine, osteine, &c.). The albuminous elements of food, however, which are now under consideration, may be derived from the vegetable or the animal kingdom; the demi-solid immediate principles are, of course, derived from animal food alone.

Uses of Albumen.—Albumen exists in the chyle and lymph, as preparatory to entering the blood. To the various secretions in which it normally exists it imparts a certain degree of lubricity. In the fluids of the eye it becomes, in connection with other immediate principles, a refracting medium.

Of the albumen in the *blood*, a part is, of course, separated in the

secretions before specified. From the rest—and this is its most important use—the various tissues are mainly, if not entirely, developed and nourished. It is, therefore, emphatically the *pabulum* of the tissues,[1] and in them becomes musculine, osteine, cartilageine, &c., as it is assimilated, in the process of nutrition, to the peculiar organic matter of muscle, bone, cartilage, and the other tissues. From it, also, the fibrine of the blood is probably formed.

Albumen, therefore, leaves the organism—1. In the secretions specified. 2. In the effete matters resulting from the metamorphosis of the tissues to which it has been assimilated; *e. g.* in the form of creatine, creatinine, urea, uric acid, &c.

Remarks.—1. Albumen is detected, if present, in urine by heat and nitric acid. (See fourth paragraph, p. 84.)

2. Styptics act by coagulating albumen—as tannic acid, acetate of lead, sulphate of copper, &c.; all these being also astringents. (§ 4.) The *fibrine* of the blood coagulates spontaneously on leaving the vessels.

3. The brain and spinal cord are hardened after death, by alcohol, creasote, nitric acid, &c. Hence these fluids are used in preserving anatomical specimens. (§ 7, p. 84.)

4. A solution of acetate of lead, applied to an ulcer of the cornea, may produce a permanent opacity. (§ 6.)

5. Albumen is an antidote to corrosive sublimate; the white of one egg neutralizing four grains of this poison.—*Peschier.* (§ 6.)

6. The sulphur combined with albumen is in an unoxidized state. Hence a boiled egg blackens silver, a sulphuret of silver being formed. Pus often blackens a silver probe for a similar reason.

7. Do the nitric and sulphuric acids check the discharges in diarrhœa and cholera, by coagulating albumen?

Pathological Relations.—In pathological states of the secreting organs, albumen may exist in almost any secretion, as saliva, gastric fluid, bile, mucus, &c. Mucous membranes may appear to secrete albumen in addition to the ordinary mucous corpuscles, when abnormally excited. (*Jul. Vogel.*) But, in all these cases, *transudation*, in addition to secretion, has occurred. Hence the presence of albumen in a fluid resembling pus is no evidence of true pus, or that it proceeded from a granulating surface.

[1] For the grounds of this assertion, see chapter on the "Histological Relations of the Blood."

Albumen may appear in the urine in a variety of pathological states, though formerly supposed to be pathognomonic of Bright's disease of the kidney. It may occur in acute as well as chronic affections of the kidney. It also not seldom appears for a short time in many acute and chronic diseases not connected with renal affections, as "inflammations of the thoracic organs, acute articular rheumatism, intermittent fevers, typhus, measles, cholera, insufficiency of the valves or contractions of the orifices of the heart; also chronic affections of the liver, and pulmonary and peritoneal tuberculosis, especially towards their fatal termination."[1] It also occurs in severe catarrh of the bladder, and in the renal catarrh supervening in erysipelas and scarlatina,[2] together with the fibrinous casts of the uriniferous tubes, such as appear in acute nephritis.

Albumen exists in the feces in diarrhœa depending on intestinal catarrh, and in cholera and dysentery.[3] As the blood becomes changed, its amount increases; and hence this symptom occurs in Bright's disease also, and large patches of epithelium may be discharged per rectum.

Albumen is an element of pus, constituting from 6.85 to 8.36 per cent. It also exists in all exudations, inflammatory or otherwise, and in all transudations (effusions), whether dropsical or not; but in the latter there is often less albumen, and always more salts and extractive matters, than in the serum of the blood.

2. *Albuminose.*

Albuminose has till recently been confounded with albumen and caseine. MM. Guillot and Leblanc mistook it for the latter. It is liquid, is not coagulable by heat, and incompletely so by acids.

Albuminose is found in the blood, constituting 4 to 6 parts in 1,000; and in the chyle resulting from the digestion of the nitrogenized (organic) substances, especially albumen, fibrine, caseine, and musculine. It is formed in the duodenum and jejunum, from the principles just mentioned in the food, and perhaps by mere isomeric catalysis. The pancreatic fluid, however, is the immediate agent of its formation thus. (*Bernard.*) Unlike albumen, it is highly endosmotic, and is not united with salts of mineral origin.[4] Entering the blood from the small intestine, it then mostly becomes albumen, or may probably at once be converted into musculine,

[1] Lehmann, vol. i. p. 308. [2] See the chapter on "Transudations." [3] Ibid.

[4] Mialhe and Pressat mean by albuminose the "endosmotic and assimilable substance finally produced by the action of gastric juice on the albumen of the food." (*Lehmann.*)

fibrine, mucosine, &c., in the solids or fluids containing these substances as immediate principles. But that it is mostly converted into albumen is probable from the fact that in diseases, if very little food (or none) is taken, it disappears in the blood, and subsequently the albumen itself also diminishes. It was this in the fluid discharged in cholera which Güterbock mistook for caseine, there being also very little albumen in choleric discharges. (*Robin and Verdeil.*)

3. *Caseine.*

Caseine is found, in animals, in milk only,[1] constituting 2 to 4 per cent., increasing as lactation proceeds, and being more abundant during an animal than a vegetable diet. Its properties generally resemble those of albumen; but all acids (as well as alcohol) *do* coagulate it, while heat *does not.*

It holds even more phosphate of lime (5 or 6 per cent.) in solution than albumen. The salts are merely mixed, and are partly precipitated with it in coagulating. A considerable quantity of water mixed with it is also set free by its coagulation.

A peculiar property of caseine is its coagulation from the contact of an animal membrane, as in the case of the curd (caseine) in making cheese. Some suppose that the pepsine in the *rennet* (the dried and salted digesting or fourth stomach of the *calf*), coagulates the caseine by *catalysis*, since the rennet will produce this effect after all traces of acidity (from the gastric fluid in it) have disappeared. Others maintain that the rennet converts the sugar of milk into lactic acid, which uniting with the alkali holding the caseine in solution, the latter is precipitated in the solid form. But caseine, like albumen and fibrine, is naturally fluid (*Robin and Verdeil*); and Lehmann remarks that the true cause of its coagulation is still unknown. The acids of the stomach will, however, also coagulate caseine, and the caseine of *human* milk is not precipitated by rennet without the assistance of acids.

[1] MM. Guillot and Leblanc, mistaking albuminose for it, have announced its presence in solution in the blood of man, woman, and several of the lower animals, and state that it is most abundant in the blood of women just before delivery and during lactation. Simon observes that it exists in the blood of lactating women if the secretion of milk is checked. Panum has also found a substance in blood-serum which he calls *serum-caseine.* It is extremely probable that caseine does exist in the blood of women during lactation, but its presence there cannot be regarded as yet demonstrated.

Origin.—Caseine is probably formed in the blood (of women) from albuminose and albumen, but nothing certain is known on this subject; and that obtained from the milk of different animals so varies in its properties, that Lehmann suggests that "caseine is not a simple organic body, but a mixture of at least two different substances. It is, also, a highly transmutable substance, often undergoing change on the application of the mildest reagents."

Uses.—Caseine exists in two forms in milk: 1. It forms the investing membrane[1] of the milk-globules, as proved by Henle and E. Mitscherlich. 2. Most of it is dissolved in this fluid.

Caseine, taken as food, probably, like albumen, is converted into albuminose in the small intestine, and is finally disposed of in the same manner. (See p. 86.)

Thus all the tissues of the young mammalia are developed for a time after birth from the caseine (and other elements) of milk, as those of birds are from the yolk of the egg.[2] It is soon coagulated by the action of the gastric fluid, and takes the form of curd, and cannot then be distinguished from coagulated albumen. The "curdling" of milk, therefore, in an infant's stomach, is no sign of disease, as is often incorrectly asserted.

The large quantity of phosphate of lime in milk adapts this fluid to the necessities of the young animals while the bones are undergoing rapid development. In adults, a less amount in the albumen of the blood is sufficient for their nutrition.

Kiesteine, a substance forming a thick pellicle, generally exhaling the odor of decomposing cheese, upon the urine of pregnant women, has been regarded as being allied to caseine, and as probably resulting from its decomposition. But Lehmann maintains that the layer is merely a formation of crystals of triple phosphate and fungoid and confervoid growths, which takes place when the urine becomes alkaline. Still, the urine of pregnant women is more likely to present it, though it is not peculiar to pregnancy. It occurs, also, in hysteria and chlorosis, and results from an increased tendency to alkaline fermentation.

4. *Fibrine.*

Fibrine is found, in its natural fluid state, in blood (.19 to .28 per cent.), chyle, and lymph (.052 per cent.), and in inflammatory exu-

[1] Sulphate of soda causes the membrane to burst when the inclosed fat is set free.

[2] Lehmann believes that the vitelline substance forming the albuminous body of the yolk of eggs is a mixture of albumen and caseine.

dations. It is, by some, incorrectly supposed to be held in solution in the serum associated with it. It is, at present, regarded as containing one atom less of sulphur, and one more of oxygen, than seralbumen, being in other respects isomeric with it;[1] uniting, like the latter, with bases as an acid, and with acids as a base. It, however, contains but from .7 to 2.5 per cent. of the phosphate of lime and magnesia.

Fibrine has been said to exist, in its *solid* state, in muscular fibre. It does not, however, exist in muscular tissue at all.

Fibrine becomes solid, or *coagulates* spontaneously, if separated from the other fluid elements of the blood; and also while in the blood, in all ordinary circumstances, if the latter be removed from the vessels and from all contact with the living tissues. After death, it also normally coagulates within the vessels.

The coagulum of fibrine is a yellowish, opaque, *fibrous* mass, soft and elastic, and containing about three-fourths of its weight of water. Thus coagulation of fibrine is *fibrillation*, and is a vital act. The coagulum of albumen has no fibres; it is merely hyaline, or minutely granular, albumen not being endowed with vital properties. Mere fibrillation is perhaps the lowest form of organization, though there is reason to believe that it is the highest of which fibrine is capable.

Any alkaline solvent of fibrine prevents its coagulation—as the sulphate of soda, nitrate and carbonate of potassa, and the chloride of sodium. Chloride of mercury probably has the same property; so also have acetic and phosphoric acid. All these substances diminish, and may destroy, the vitality of fibrine.

Origin of Fibrine.—The fibrine of inflammatory or other exudations is, of course, derived wholly from the blood. That in the

[1] Dumas states that fibrine contains less carbon and more nitrogen than albumen. Carpenter says it contains (according to most analyses) more oxygen than albumen, and that it is probably albumen *oxidized* by the process of aeration.

The chemical composition till recently assigned to these three immediate principles, regarding them as *proteine compounds*, is as follows—assuming Mulder's original formula for proteine ($C_{40}H_{31}O_{12}N_5$), or Liebig's ($C_{41}H_{36}O_{14}N_6$), and its combining number being 437.3 (*Mulder*), or 526 36 (*Liebig*) :—

	Mulder.	Liebig.
Seralbumen is 10 proteine + PS_2; combining number,	4436.56	5327.16
Fibrine and ovalbumen, 10 proteine + PS; comb. number,	4420.47	5311.07
Caseine and crystalline, 10 proteine + S; comb. number,	4389.09	5279.69

Mulder's more recent formula for proteine is $C_{36}H_{25}N_4O_{10}+2HO$.

blood is obtained in part from the chyle and the lymph; but it is also probably formed, in all three of these fluids, from their albumen. Were we content with a mere chemical hypothesis, we might adopt Lehmann's as the most plausible, viz., that "fibrine is produced by the oxidation of albumen in the aeration of the blood, while the conversion of fibrine into the tissues is also the result of an oxidation of fibrine. But fibrine is increased in inflammation, not because of more oxygen in the blood, but because there is less than usual; there being *barely enough to form the fibrine from the albumen, but not enough to secure the metamorphosis of the latter.* Hence the highest amount of fibrine is found in pneumonitis, the disease in which the aeration of the blood is most impeded." But *oxidation* is mere *chemical action;* and it is entirely abhorrent to our ideas of nutrition, that the tissues are formed from any immediate principle by an exertion of mere chemical force. Each tissue possesses the power of assimilation, by which is meant the power of forming its own substance from materials in the blood, which are never, as there found, precisely identical in composition with itself. So it is probable that fibrine, possessing vitality, develops itself from the analogous compound, albumen, and fat, and a few saline substances.[1] So, also, it is probable that fibrine undergoes its own metamorphosis, in the blood or out of it, as the tissues do; and when it is formed in excess in the blood, this may be owing to either an excess in its development, or a diminished metamorphosis, or to both combined.

Uses of Fibrine.—1. The fibrine in the blood gives to it the power of coagulating, and therefore, within certain limits, of spontaneously arresting hemorrhage. In case of ligation of a vessel, also, it is the fibrine which prevents the escape of blood when the ulcerative process excited by the ligature cuts off the vessel.

2. Fibrine present in exudations forms the *nidus* in which adventitious growths are developed, or in which new tissues are formed, as in case of the reparative process. Fibrine appears also to be the forerunner of the original tissues, or the matrix in which they are at first laid down during intra-uterine development; but, in the last two cases, the fibrine, after fulfilling its temporary office, disappears. It is probable that the fibrine of the blood does not normally con-

[1] For fibrine is probably a compound, and not a simple substance; as is also the case with caseine. See "Remarks" following.

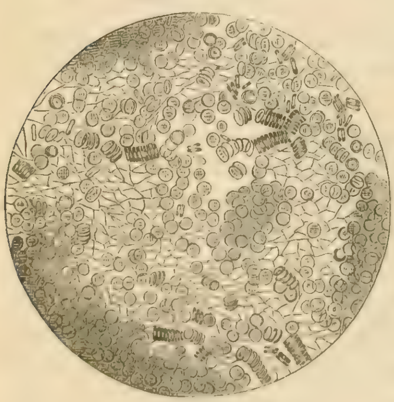
duce to the nutrition of the permanent tissues,[1] and that it becomes itself permanent only in persistent false membranes, and other similar pathological epigeneses.

Fibrine is probably converted, in its final metamorphosis, into urea, uric acid, and other effete substances, like albumen and the proper tissues.

Remarks.—I. It is not probable that what is called fibrine is a simple substance. It always contains salts, sulphur, and fat—even 2.6 per cent. when dry. Besides, Lehmann remarks that it is "wholly at variance with all preconceived ideas to attribute life to a simple organic substance;"[2] and fibrine manifests a property which can hardly be otherwise than vital, viz., *spontaneous coagulability.*

II. Normally, the fibrine coagulates in human blood to such an extent as to give the blood a gelatinized appearance in from two to four minutes; in inflammation, this appearance is delayed ten to fifteen minutes, or longer. In case of filtered frog's blood, or of inflammatory exudations (the red corpuscles being in both of these cases separated from the rest of the blood, so that no obstruction is offered to the process or to the view), molecular granules are first seen in the clear fluid, at various points, from which very fine straight threads are next seen to radiate. (Fig. 43.) The latter do not, however, form star-like masses like crystallization, but they finally cross each other in all directions, and inclose the colorless corpuscles (if present), so that they can hardly be distinguished in the network. As coagulation occurs in ordinary circumstances, the fibrine at first incloses *all* the other constituents of the blood, and the whole mass of blood appears to have gelatinized. But the contraction of the fibrine becoming more advanced, the serum is squeezed

Fig. 43.



Fibres in coagulating blood.

[1] See chapter on the "Histological Relations of the Blood."

[2] Chemistry, vol. i. p. 313.

from its meshes, and rises on the surface, while the corpuscles (colored and colorless) remain inclosed in the coagulum. Sometimes the coagulum is not fully contracted under forty to forty-eight hours. When the fibrine is left separate from all other elements, its threads or fibrils alone occupy the field of vision, and afford a striking resemblance to the membrane lining the egg-shell. (Fig. 48.)

III. Coagulation is *fibrillation*, and is to be regarded as a vital act, since it is organization, though perhaps of the lowest kind. But fibrillation is the last and the highest vital act of the fibrine. The more highly vitalized, therefore, the fibrine, the slower and the more perfect the fibrillation. Hence, as it would seem, inflammatory blood both coagulates most slowly, and affords the most complete fibrillation. Indeed, the solidification is so long retarded (ten to twenty minutes), that the corpuscles—the heaviest portion of the blood—have time to subside, and thus leave the upper portion of the clot of a light straw color; and which has given to the coagulum, in such cases, the name of the "buffy coat." This is characteristic of inflammation, however, only when due to *slow* coagulation. It occurs, also, in anæmia and chlorosis; the coagulation being rapid in these conditions, but the red corpuscles in the blood being so deficient as not to give the usual bright red color to the coagulum.

IV. The fibrillation of fibrine is the more perfect in all the following conditions:—

1. When its *vitality is apparently highest*, as in inflammation; when also coagulation is most slowly performed.

2. When it is most nearly isolated from the other elements of the blood, especially the corpuscles, as in inflammatory exudations, which consist of fibrine and serum only in all cases except when hemorrhage also has occurred.

3. When its *contact is most perfect with the living tissues*, as in case of inflammatory exudations upon serous membranes, when the exudation is, of course, in contact with the tissues on *both* its surfaces. In case of inflammation on mucous membranes, or the skin, the exudation can be in contact only on one surface, except in the rectum, vagina, &c. Hence false membranes, so called, which are originally mere fibrillated fibrine, are more common on serous surfaces, and very uncommon on mucous membranes, except those just mentioned.

4. When it is at *perfect rest after leaving the bloodvessels*. Here, again, a serous membrane has the advantage. In pleurisy and peri-

tonitis the acute pain accruing from motion secures rest of the diseased part. Mucous membranes, lining canals for the passage of foreign substances, are, on the other hand, unfavorably situated in this respect, since the latter may disturb the contact of the exudation, or even remove it entirely. The latter, however, often does not occur, and therefore false membranes (falsely so called[1]) may be formed on the pharynx, in the rectum, the vagina and uterus, and the nasal passages; and in the larynx, trachea, and bronchial tubes, especially of young children.

5. When a *temperature of* 98° *to* 100° *Fahr. is uniformly maintained.* Here an internal surface or part has the advantage.

V. On the other hand, all the circumstances opposing the conditions just mentioned render the fibrillation less perfect. These need not be specified at length. Any agent reducing the vitality of the fibrine, diminishes the probability of the formation of a false membrane, in case of inflammation on a serous surface. Alkalies, nitrate of potassa, and the salts of mercury (the protochloride especially), appear to possess this property, causing the exudation to remain longer fluid, and thus prolonging the opportunities for its reabsorption. Hence, if these agents are administered too freely, and especially when the fibrine has already a low vitality (as in scrofulous subjects), the exudation may be converted into pus instead of a false membrane. Empyema may thus be produced from pleuritis, in a delicate patient.

VI. The coagulation of the blood may be *entirely prevented* by any cause which at once destroys the vitality of the fibrine. Such are—

1. *Poisons in the blood*, as in case of malignant typhus, or of glanders; or of retention in the blood of deleterious secretions, as carbonic acid gas (in asphyxia), urea (in suppression of urine), &c.

2. *Violent shocks to the nervous system*, as from mental emotions, or in cases of death from lightning.

3. *Too high a temperature.* A heat of 180° destroys the vitality of the fibrine, and coagulates the albumen of the blood.

VII. The following agents *retard* the coagulation of the blood:—

1. *Extreme cold.* If blood is, however, *frozen at once on being drawn*, it coagulates on being thawed.

2. Certain narcotics and sedatives, as opium, belladonna, aconite,

[1] See section on "False Membranes."

hyoscyamus, digitalis, and strong infusions of coffee and tea. (Carpenter, *Principles, &c.*, p. 195.) Carbonic acid also produces the same effect.

3. The addition to the blood of solutions of albumen, caseine, or sugar, retards its coagulation. On the contrary, violent agitation and a watery condition of the blood, and free access of the air, hasten the coagulation.[1]

VIII. Fibrillation being the only distinguishing histological characteristic of fibrine, it is clearly unphilosophical to assume that an amorphous mass of organic matter in the organism is fibrine, merely because it is solid, as in exudations, in tubercle, &c. It is far more probable that such masses are merely albumen, and not fibrine. It has already been shown that it is not possible always to identify and distinguish albumen and fibrine in their solid form. (p. 85.) Fibrils alone demonstrate the latter; while their absence merely leaves the inference probable that the substance is albumen, but *proves* nothing.

IX. Since fibrine is indispensable to the original development of the tissues, and to the reparative process, as it affords the matrix for the new growth, all the agencies mentioned as interfering with its perfect fibrillation are obstacles to these processes also.

X. The fluid substance from which the tissues are directly formed, or repair is secured, is called "plasma," "blastema," "hyaline substance," &c. It is, in fact, the liquor sanguinis, *i. e.* the *whole blood*, except the two kinds of corpuscles. It was formerly called "coagulating lymph" by Hunter and others.

XI. The idea generally entertained, that fibrine is the only plastic element of the blood, must now be received with suspicion. It is merely the only spontaneously plastic or organizable element, and the *first* organized—the *primum organizatum*—of the blood.

XII. Since fibrine, by its coagulation, spontaneously arrests hemorrhage from the smaller vessels, the hemorrhagic tendency in purpura, scorbutus, and in some persons constantly, though in health, seems due to a low vitality of the fibrine, or an insufficient quantity.

XIII. Finally, the "polypi," so called, which are often found in the heart after death, are mere masses of coagulated fibrine.

[1] It should be added here that Dr. B. W. Richardson, of London, has recently received the Astley Cooper prize for his investigations, tending to demonstrate that the fluidity of the blood (i. e. of the *fibrine*) is due to the presence of free ammonia.

SECOND DIVISION.

Solid or Demi-solid Immediate Principles.

These are the most abundant of all the organic substances, and while the principal substances in the preceding division (albumen, albuminose, and fibrine) are found in the blood, all these (except globuline and crystalline) exist in the *tissues*. These, therefore, are of great interest to the histologist; though most of them have been so recently announced, that our knowledge of them is still limited. They are seven in number.

1. *Globuline.*

Globuline is found only in the red corpuscles of the blood. The globuline, together with the hæmatine (the hæmato-globuline), constitutes most of the viscid fluid contents of the blood-corpuscles. The precise proportion of each has not yet been ascertained. Robin and Verdeil remark that the globuline constitutes the principal part of the mass of the corpuscles.

Globuline is not soluble in serum, but is so in water, which, in dissolving it, destroys the corpuscles. It is in the latter united, molecule to molecule, with the hæmatine and with some fatty substances.

Origin.—Since globuline is found only within cells (blood-corpuscles) bathed by an albuminous fluid, we can hardly avoid the conclusion that it is developed from albumen by the action of the cell-membranes. Those who believe in the oxidation process as forming fibrine from albumen, regard globuline as an intermediate substance between albumen and fibrine; but that it is at all converted into fibrine, is merely a chemical hypothesis.

Uses.—The use of globuline in the blood is unknown. It probably exists in it for the direct advantage of the blood itself, and not as a *pabulum* for the tissues.

Globuline probably undergoes its own peculiar metamorphosis in the blood, but nothing is known on this point.

2. *Crystalline.*

This substance exists only in the crystalline lens, and has been regarded by some chemists as identical with globuline. Lehmann has, however, recently asserted that they are distinct substances,

though he strangely applies the name crystalline to the immediate principle in the blood-corpuscles, and calls that in the lens globuline. Hence he terms the mixture of hæmatine and the other immediate principles hæmato-crystalline. We have applied the name hæmato-globuline to the same (p. 96).

In the human crystalline lens, Berzelius found 35.9 per cent. of dry crystalline; which also contains .241 per cent. of phosphate of lime. It probably also contains phosphate of soda and ammonia. (*Lehmann.*) Some of these salts exist in abnormal amount in case of hard cataract.

Origin.—Crystalline is probably formed from the albumen in the albuminous fluid (aqueous and vitreous humors of the eye), surrounding the crystalline lens.

Uses.—Crystalline is a refractive medium in the crystalline lens, as albumen is in the other humors of the eye; and Chenevix first made the observation that this principle is more concentrated in the central than in the peripheral portions of the lens, to render it achromatic.

3. *Musculine.*

Musculine—also called syntonin[1] by Lehmann—exists in contractile tissue alone, *i. e.* in both the striated and the non-striated muscular tissue. Its precise amount in human muscle is not yet determined. Most, if not all, that has been called fibrine in muscular tissue is actually musculine. In the ox it constitutes 60 to 85 per cent. of the *solid* portion of the muscles, or 15.4 to 17.7 per cent. of their substance. In the calf it does not amount to more than 50 per cent. of the solid matter.

Musculine is soluble in water containing one-tenth its weight of hydrochloric acid; blood-fibrine merely swells in this, but does not dissolve. Musculine contains 1.4 per cent. of phosphate of lime, but no iron, while the latter is found in blood-fibrine.

Musculine is always associated, in muscle, with albumen, creatine, and creatinine, inosic and lactic acids, chloride of sodium and potassium, &c.;[2] but these all exist in the *muscular juice*, which will be discussed in the chapter on "Contractile (Muscular) Tissue."

[1] From συντείνειν, to strain.

[2] Scherer has recently found inosite, or *muscle sugar*, also in the muscular juice of the heart of the ox.

Origin.—There is no reason to doubt that musculine is formed from the albumen (and albuminose) in the blood. The necessity for admitting that muscular tissue is formed from the blood-fibrine ceases to exist when it is demonstrated that fibrine does not exist in it. And no physiological objection occurs to the idea that albumen may be directly converted into musculine as readily as into fibrine. How the conversion occurs, in either case, is unknown.

Uses.—Musculine is the main constituent and essential substratum of the contractile (muscular) tissue. It, especially, is endowed with the vital property of *contractility*, though other immediate principles are doubtless united with it, molecule to molecule, and without which it could not manifest the property just mentioned. It forms the fibrils of striated muscular tissue, and is always bathed in a fluid of an acid reaction, called the muscular juice. The latter, however, results, probably, in great part at least, from the metamorphosis of the musculine; and since it contains creatine, creatinine, lactic acid, &c., these substances are doubtless the immediate results of its transformation.

Remarks.—Fresh muscular fibre, even of inferior quality, nourishes an animal indefinitely; while blood-fibrine, with the addition of soup, nourished only about a month, when the animal refused for three days to take it. (*Magendie.*) Of the former, 150 to 300 parts are better than 1,000 of blood-fibrine, with some albumen added. (*Robin and Verdeil.*)

Boiling converts musculine into a substance allied to gelatine; roasting does not. Hence boiled meat is far less nutritious than the same when broiled or roasted.

Musculine is more abundant in the muscles of the ox and of the common fowl, than in those of the sheep. Hence beefsteak is one of the most nutritious substances for the muscular system of man. It is also much more so than veal, since there is less musculine in the muscles of young animals.

4. *Osteine.*

This is the name given by Robin and Verdeil to the still undescribed substance from which glutin (or gelatine) is obtained by the action of boiling water; for glutin does not naturally exist in the human body.

Osteine exists in bone and in white fibrous tissue, wherever found (in tendons, ligaments, the cornea); and in permanent cartilages when

they become *ossified* in disease. In fishes it exists in the swimming-bladder and in the scales.

The chemical composition of osteine is unknown. It probably differs from glutin by a few atoms of water, at most. (*Lehmann.*) But the composition of the latter is not yet settled; Liebig's formula being $C_{52}H_{40}N_8O_{20}$, while Mulder's is $C_{13}H_{10}N_2O_5$.

Osteine constitutes a large part of the mass of the human organism. Haller remarked that "one-half of the human body is glutin." In fact, one-half of the solid part of the body is *convertible into glutin by boiling in water.*

In the bones, osteine is chemically combined with the phosphate of lime, and constitutes from 17.3 to 27.99 per cent. of the bone-substance; water constituting from 47.22 to 22.87 per cent. (*Magendie.*)

Origin.—Osteine is formed in the tissues in which it occurs, by assimilation of the albuminous elements of the blood, like globuline and musculine.

Uses.—Osteine is the essential organic element in bone and white fibrous tissue. It, however, manifests but very low vital endowments, merely in the way of nutrition and reproduction, in these tissues. Hence the latter belong to the lowest class, and are useful only on account of their physical properties; the bones giving support to the body and strong points for the attachment of muscles, and the white fibrous tissue subserving various uses on account of its strength and flexibility, and its almost total inextensibility. The cornea is useful from its strength and transparency.

The transformations of osteine are not understood.

Remarks.—Osteine is nutritious and assimilable; glutin is not, but, if it enters the blood, appears in the urine. Hence Magendie found that animals may be sustained indefinitely by giving them finely ground bones, while they soon languish if they are fed with soup obtained by boiling the bones; since in the latter case the osteine is converted into glutin.

5. *Cartilageine.*

The substance which by the prolonged action of boiling water is converted into chondrine, is named cartilageine. (*Robin and Verdeil.*) It is found only in cartilages and in fibro-cartilages. It exists abundantly in the intercellular substance of cartilage; whether in its cells, also, is not certainly ascertained.

Cartilageine exists in bone-cartilage as well as in the permanent

variety; but as soon as ossification occurs in the former, osteine is found, and cartilageine disappears as the process goes on.

The chemical composition of cartilageine probably differs very little from that of chondrine; but even the latter is not yet decided. Mulder's formula is $C_{32}H_{26}N_4O_{14}$; Liebig's, $C_{48}H_{40}N_6O_{20}$. The origin of cartilageine is not definitely decided, but it is probably formed directly from the albuminous elements of the blood. Nothing is known of its metamorphoses.

Uses.—Cartilageine is the essential organic element of cartilage, and in which the vitality of this tissue especially resides. It, however, manifests even a lower vitality than osteine in the way of nutrition and reproduction; and hence this tissue is useful merely on account of its physical properties, and especially of its elasticity.

Remarks.—The idea is untenable that glutin is formed from chondrine—or, rather, that osteine is formed from cartilageine—because bone is formed from cartilage; for as bone merely *replaces* cartilage, so the osteine replaces the cartilageine. Attempts, therefore, to explain how either of these immediate principles is formed from the other, are both uncalled for and unproductive.

Müller has shown that in cases of softening of the bones, where there is a diminished amount of the phosphate of lime, neither glutin nor chondrine is obtained by boiling them.

6. *Elasticine.*

This is the peculiar organic element in the yellow fibrous or elastic tissue. (*Robin and Verdeil.*)

Its chemical composition is not determined, nor is its amount in the tissue above mentioned.

Uses.—It possesses but a very low degree of vitality; hence the elastic tissue subserves merely physical requirements. Its great extensibility and elasticity are its characteristic properties.

7. *Keratine.*

Keratine is the organic immediate principle peculiar to epidermis, nails, hair, wool, and horn.

A small amount of the fatty principles is chemically combined with this principle.

Uses.—It is doubtful if keratine possesses vitality. At all events, it merely gives hardness and other physical properties to the tissues

just mentioned, and which are constantly falling off from the body as excrementitious.

THIRD DIVISION.

Coloring or Colored Organic Substances.

Under this head are included—

1. Hæmatine—the coloring matter in the blood-corpuscles.
2. Biliverdin—in the bile.
3. Melanine—in melanotic deposit, &c.
4. Urrosacine—in urine.

1. The *urine-pigment* is of no importance in histology, and will be merely mentioned here.

2. The *bile-pigment*, also, will be but briefly alluded to. The biliverdin is the green, the cholepyrrhin (*Berzelius*) or biliphaein (*Simon*) is the brown, and the bilifulvin is the yellow, coloring-matter of the bile. The last is entirely converted into hæmatoidine (see p. 102), and is formed in stagnant bile as hæmatoidine is in stagnant blood.

The greenish color of the feces (as in diarrhœa) is generally due to an admixture of decomposed blood, and rarely to the presence of biliverdin. Bile-pigment is, however, never entirely absent from the feces, except in some rare cases of icterus. Nothing is known of the origin of the bile-pigment. It is probably not formed in the liver. (*Lehmann.*)

In diseases, bile-pigment may be found in the urine, in the fluid of the areolar tissue, and even in the sweat and the saliva. It is also deposited in all the fluids of the eye, and in the sclerotic coat. Sometimes, indeed, the saturation of the organism is so extreme as to color the cartilages, ligaments, bones, and even the nerves.

3. *Hæmatine.* ($C_{44}H_{22}N_3O_6Fe$.)

Hæmatine occurs only in the red corpuscles of the blood of the higher animals, and gives the latter its bright red color. It constitutes 1.675 per cent. of the moist corpuscles, and about .73 per cent. of the whole blood; but this substance obtained by the chemist is not the coloring-matter as it naturally exists in the corpuscles, but is a product of its metamorphosis. It is naturally dissolved in the globuline in the corpuscles, but can be obtained only in its coagu-

lated—and, of course, modified—condition. Its combining number is 5175. (*Mulder.*)

Iron is always found in combination with hæmatine; but whether in the state of an oxide or not, is not yet decided. It is, however, not probable that the single equivalent of this metal is chemically combined with the group of atoms representing pure hæmatine, $C_{44}H_{22}N_3O_6$ (*Mulder*), and it is demonstrated that iron may be abstracted from the hæmatine without affecting its bright red color. It constitutes 6.64 per cent. of the hæmatine (*Mulder*), and .38 per cent. of the dried red corpuscles (*Berzelius*); and about .05 per cent. of the blood. Iron also exists in chyle and in the colorless parts of the blood.

Hœmatoidine (otherwise called xanthose) was first observed by Virchow, and is found in amorphous or jagged masses, in granules, in globules, or in perfectly formed crystals. It always occurs in corpora lutea, and often in old extravasations in the brain, in obliterated veins, in subcutaneous suggillations, and in purulent abscess of the extremities. (*Virchow.*) It may be found in extravasations at the end of seventeen to twenty days. Its crystals are of a yellowish red, a red, or a ruby color. It is doubtless formed from hæmatine, resulting from the metamorphosis of the latter. It has also been stated that it may be formed from bilifulvin (p. 101).

Origin.—Nothing is known of the origin of hæmatine. It exists in the thoracic duct, but may have entered it from the blood in the mesenteric glands, or have come from the blood-corpuscles which have passed into the chyle with the splenic lymph.

Doubtless, however, the hæmatine is first formed within the membrane of the colored blood-corpuscles; and the most probable hypothesis is that of Lehmann, according to which hæmatine is formed from fat,[1] by its oxidation.

Uses.—The constant occurrence of hæmatine in the blood-corpuscles of all the higher animals leaves no doubt of its importance, but its precise use is not yet determined. It, however, gives to blood the color by which we may at once distinguish it from all the other animal fluids. It has also been supposed to be especially connected with the respiratory process. The experiments of Brüch and Harless show that the inspired oxygen acts on the corpuscles and their contents, and, of course, upon the hæmatine; but what the

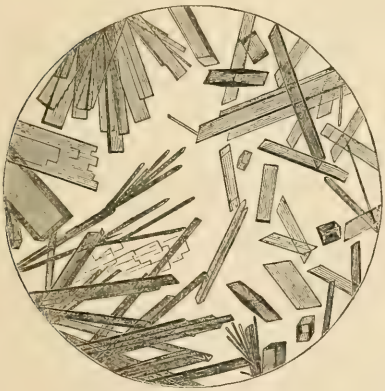
[1] Physiological Chemistry, vol. i. p. 273.

precise action is, can still be only conjectured. And yet the idea that the hæmatine or the corpuscles are alone or mainly acted upon by the inspired oxygen seems to be weakened by the observations of Hannover, which show that chlorotic persons, whose blood is poor in red corpuscles, exhale as much carbonic acid as healthy persons.

The probability that hæmatine is finally transformed into hæmatoidine has already been shown. From it, also, melanine is probably derived.

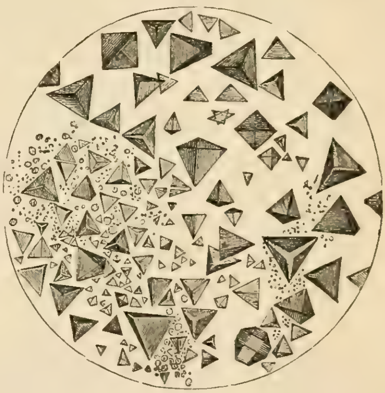
In connection with hæmatine should be mentioned the red crystals first observed and obtained from the red blood-corpuscles by Funke, and which Lehmann terms the albuminous crystalline substance of the blood. Fig. 44 shows the form of these crystals in

Fig. 44.



Crystals of human venous blood.

Fig. 45.



Crystals from blood of the guinea-pig.

human blood, and Fig. 45 those obtained from the corpuscles of the guinea-pig. They are not formed till after the corpuscles burst.

The relation of these crystals to hæmatine is, doubtless, important; they being the substance from whose metamorphosis hæmatine is probably produced.

4. *Melanine.*

This is the dark pigment found on the choroid coat of the eye, and in pigment-cells generally. The melanotic deposit, so called, also probably consists of it. Its formula is not yet ascertained. It is certain that the pigment often deposited in the lungs as a morbid

product varies much in composition, and abounds in carbon—66 to 72 per cent. (*Schmidt.*) Melanine occurs in the black serum which has sometimes been observed.

Melanine is, doubtless, derived from hæmatine. In the choroid coat it contains .254 per cent. of iron. (*Lehmann.*) It occurs within all pigment cells, in the form of granules; and in other cases, especially in melanotic tumors, it is also found scattered among cells or tissues. In the choroid coat of the eye this pigment is, doubtless, subservient to vision. For other particulars, see the section on "Pigment-cells."

Having thus completed the description of the immediate principles of which the solids and fluids of the human body are composed, we next enter upon Histology proper.

PART II.

HISTOLOGY.

DEFINITIONS, SUBDIVISIONS, ETC.

HISTOLOGY[1] is the scientific classification and description of the structural[2] or organized elements of the solids and fluids of living organisms. Since these elements can be demonstrated only by the aid of the microscope, Histology is one of the subdivisions of minute or microscopic anatomy.[3] It also includes Histogeny, or the development of the elements just mentioned.

Animal Histology, Vegetable Histology, and Human Histology, are terms requiring no special explanation. Comparative Histology is the study of the structural elements of the lower animals. Pathological Histology is the study of the minute structure of the organism as modified by disease.

If we investigate the structural elements in their general relations only, and without regard to their distribution in particular parts or organs, this is *General Histology;* if in regard to the latter particulars, it is *Special Histology.*

Thus explained, the present is a treatise on Human Histology, both general and special, and, at the same time, both *physiological* and *pathological.* Thus the subjects it includes will be found to

[1] From ἱστὸς, a web or network, and λόγος, description.

[2] "Morphological elements" is a phrase sometimes employed in the same sense.

[3] Histology may, indeed, be regarded as *general microscopic anatomy.* If we investigate microscopically merely the structure of a part or organ, without any ulterior object, this is *special microscopic anatomy.* And if we thus investigate the structure of the various organs with the view to establish their functions, or scientifically to associate the latter with the structure, we are contributing to the department now known as *physiological anatomy.*

underlie the whole domain of anatomy (as usually taught), and of physiology and pathology. *Comparative Histology* will also be introduced, especially so far as it gives interest, by its analogies or its contrasts, to the study of the tissues in the human organism.

The structural elements of the human organism may be arranged in two classes:—

I. *The simple histological elements.*
II. *The tissues, properly so called.*

The second part of this work will consist of three divisions, containing—

I. A description of the simple histological elements, their distribution, development, &c.
II. Of the fluids in the human body which contain histological elements.
III. Of the tissues, properly so called.

FIRST DIVISION.

THE SIMPLE HISTOLOGICAL ELEMENTS.

THE various structural *forms* presented to the histologist in the solids and fluids of the human body may be included under the five following heads:—

I. Homogeneous substance.
II. Simple membrane.
III. Simple fibre.
IV. Cells.
V. The tissues proper.

All these are developed from the elements in the blood which are required for their nutrition, and in a manner to be described in connection with each.

The four first mentioned of the preceding forms constitute the simple histological elements, or elements of which the proper tissues are directly or indirectly formed, and will be first of all considered.

CHAPTER I.

HOMOGENEOUS SUBSTANCE.

BY this is meant a more or less solid, structureless substance, which enters into the composition of several of the tissues. In a thin section it resembles a mere layer of solidified albumen.

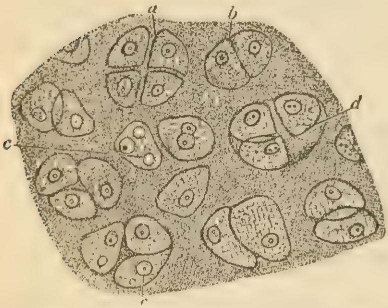
It often fills up the spaces between the fibres or the cells of compound tissues; *e. g.* cartilage and fibro-cartilage. Consequently it may constitute a large part of the mass of certain tissues. Of pathological epigeneses, it exists in cancer, sometimes forming a large

part of its mass, and giving it its hardness. (*Gluge*, p. 37.) It is, also, one of the elements of tubercle.

From its structureless appearance, and its transparency when seen in section, it has also been termed *hyaline* substance.[1] In relation to the other elements of compound tissues, it is sometimes termed a *homogeneous matrix*, in which the other elements (cells, fibres, &c.) are said to be imbedded.

In some cases, however, minute granules appear in this histological element. Its two forms, therefore, are the *hyaline* and the *granular* homogeneous substance. When in its lowest form, as in some cancers, it seems to be mere coagulated albumen. In the tissues, however, the homogeneous substance appears always to have attained to a higher stage than mere albumen, though it is very probably always developed from that element in the blood. For example, the homogeneous matrix of cartilage contains cartilageine, and not albumen, while that of bone and dentine contains osteine only. On the other hand, some cancerous deposits afford merely albuminous products on being boiled, while others afford gelatine, and thus show that osteine existed in them. In the latter case, however, there are fibres of white fibrous tissue, as well as homogeneous substance, in the cancerous deposit, and this tissue may have afforded all the gelatine to the boiling water (p. 98).

Fig. 46.



Homogeneous substance and cells of cartilage *a*. Group of four cells, separating from each other. *b*. Pair of cells in apposition. *c*, *c*. Nuclei of cartilage cells. *d*. Cavity containing three cells. The granular homogeneous substance is seen between the cells.

Origin.—If the lowest form of homogeneous substance, whether granular or not (as in cancer), appears to be simply coagulated albumen, it is really something more—something possessed of vital endowments—in all the tissues; though probably formed from the albumen of the blood, in each of them, by assimilation.

Functions.—In its lowest form, it, therefore, hardly does more than serve as a cement to connect other histological elements to-

[1] From ὕαλος, glass, it resembling a lamina of this substance.

gether; while in its higher developments, as in bone, &c., it manifests the vital functions characteristic of the tissue of which it forms a part. The latter are, however, always of a low grade, as mere nutrition and reparation, since all the tissues in which it abounds are useful rather from their mechanical than their vital properties.

Distribution.—It abounds in bone and cartilage, and in the morbid developments already mentioned.

In *pathological* states, homogeneous substance may undergo a fatty degeneration (*Wedl*), oil-globules being deposited in it. Pigmentary substances are also often found in it.

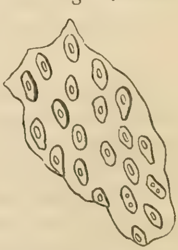
CHAPTER II.

SIMPLE MEMBRANE.

Simple membrane usually appears as a very thin, transparent, and perfectly structureless layer of coagulated albumen or plasma, often not more than $\frac{1}{20000}$ of an inch in thickness. It is nourished by vessels lying near or under it, but is never penetrated by any vessel, nerve, or, indeed, by any other tissue whatever. It is entirely imperforate at every part, the highest powers of the microscope never revealing any pores, or openings of any kind. Forming, therefore, a complete barrier between the structures on its opposite sides, it has, in some parts, been termed a *limitary* membrane.

The posterior layer of the capsule of the crystalline lens affords an excellent illustration of this kind of tissue. Being structureless and transparent, it can, however, only be seen when accidental folds or other irregularities are formed. (*Queckett*, p. 116.)

Fig. 47.



Basement membrane of intra-glandular lymphatics.

In some case, however, granules also appear in simple membrane; and in a third form of it distinct spots appear, which have been regarded as nuclei; and it may be broken up into separate portions, each containing one of these. (Fig. 47.) If the simplest form is solidified albumen or plasma, the second is probably the same sub-

stance, containing granules in it; and the third form is an instance of the development of scales from germinal points, or nuclei, as cells are normally developed (Chap. IV.), and which scales coalesce at their borders to form the continuous layer. In all these cases, however, it is organized, and manifests vital properties.

Simple membrane is found only in two conditions, except when an element of the compound tissues, viz., in the form of a membranous expansion, to constitute—

1. Basement membrane, which will be described at the end of this chapter.

2. As constituting the walls of cells, whether secreting, absorbing, or primordial, &c. &c.

Properties of Simple Membrane.—Though the simplest of the histological elements, it manifests important vital properties. Since it forms the walls of cells (secreting and otherwise), simple membrane is the direct agent of *secretion* in all cases. It is also, in many instances, of *absorption.* These are, therefore, its two *vital* properties. The physical property of endosmosis also inheres in it in a remarkable degree.[1]

Distribution of Simple Membrane.—The basement membrane of the skin, and of serous and mucous membranes, is formed of this element. It therefore enters the lobes and follicles of all glands. It forms the capsule of the crystalline lens, and the posterior layer of the cornea. It lines the bloodvessels and the lymphatic vessels, in the form of epithelium, if not of a basement membrane also.

It forms the walls of all cells, whether blood-corpuscles, secreting cells, fat-cells, &c. &c.[2]

As an element of compound tissues, it also constitutes the myolemma of the muscular fibres, and the neurilemma of the nerve-fibres or tubes.

Simple membrane will, therefore, constantly recur in the descrip-

[1] By endosmosis is meant the property inherent in animal membranes, of transmitting fluids through them. If two fluids of different specific gravity are placed on opposite sides of them, they are transmitted in opposite directions, and thus mixed—one current being termed endosmosis, and the other exosmosis.

[2] Simple membrane also forms the walls of the cells from which the tissues of vegetables are developed; it being identical in them, it is said, with cellulose, $C_{24}H_{21}O_{21}$, or C_8+Aqua$_7$. It is an interesting fact, if verified by future investigations, that the vegetable cell is lined by a "primary utricle" or cell, identical in composition with proteine—*i. e.* it is an albuminous compound, as is the animal cell-wall.

tion of cells and of the various tissues; and, in connection with these, its important vital relations will be particularly indicated.

Basement Membrane.

A basement membrane is a mere expansion of simple membrane entering into the structure of the skin, and all mucous and serous membranes, and lying directly upon the corium of these structures respectively. It is itself covered, in turn, by the epithelium of the serous and mucous membranes, and the epidermis of the skin. Its thickness is often not more than $\frac{1}{20000}$ of an inch.

Kölliker does not mention the basement membrane at all as an element of the three tissues just mentioned. There is, however, no doubt of its existence in many parts of them. It has been shown that simple membrane presents three forms; and Queckett asserts the probability that in one or another of these, basement membrane exists in every part of the three membranes just mentioned.

Uses.—The basement membrane is a complete barrier between the vessels and nerves of the corium on the one hand, and the epithelium on the other, being never perforated by any structures whatever. It thus rises over and covers the villi of the small intestine, and the papillæ of the skin. It also dips down into and lines all the sebaceous follicles and sweat ducts of the latter, and the mucous follicles of the former. Thus it forms everywhere the basis of the epidermis and of epithelium. Whether it secretes from the vessels under it the plasma from which the epithelial cells are developed, is uncertain. This has been supposed to be the fact; but this supposition is, at least, quite improbable.

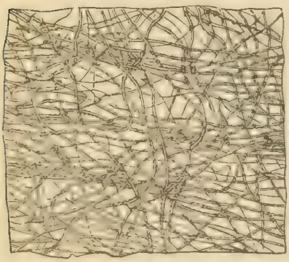
A basement membrane is said by some to exist as a distinct structure in the lining membrane of the bloodvessels also. This assertion still needs confirmation, though the presence of a kind of epithelium there suggests the idea of its presence also from analogy. Kölliker asserts the contrary.

CHAPTER III.

SIMPLE FIBRE.

FIBRES enter into the composition of some of the compound tissues; and two of the simple tissues—the white and the yellow fibrous tissues—are formed of them exclusively. Simple fibre is, however, something entirely different from these, and sustains to them no higher comparative rank than do the lower forms of homogeneous substance in comparison with osteine.

Fig. 48.



Simple fibres of membrane lining the egg-shell.

An example of simple fibre, always easy to obtain for illustration, is found in the membrane lining an egg-shell (membrana putaminis), which consists of several layers, each formed by the interlacement of simple fibres. (Fig. 48.)

Pure coagulated fibrine also consists merely of a network of simple fibres (p. 92).

Simple fibre appears always to consist of mere threads of coagulated fibrine. In other words, it appears to be merely the result of the *fibrillation* of fibrine already described (p. 93). These threads average about $\frac{1}{8500}$ of an inch in diameter. Of course they are less perfectly developed in the circumstances in which coagulation is less perfect (p. 95). On the other hand, they are most perfectly developed in inflammatory exudations.

Fig. 49.

Simple fibres in inflammatory exudation from peritoneum.

The human chorion appears to

be formed at first exclusively of simple fibres. These, however, subsequently disappear, as its development proceeds.

There is reason to believe that simple fibres constitute the *matrix* in which the tissues generally are developed during embryonic life, as well as the *nidus* in which repair takes place after solutions of continuity with or without loss of substance (p. 91).

Uses.—Simple fibre is, therefore, not a permanent constituent of the human body. It must be regarded as a merely temporary element, laid down as a framework on which higher histological elements may be developed, and which then becomes absorbed and disappears.

In this way, however, its relations to the tissues are all-important. Since, also, coagulated fibrine consists of a network of similar fibres, they become the medium for the spontaneous arrest of hemorrhage, as before explained (p. 91).[1]

In pathological epigeneses four kinds of fibres are found: 1. *Cleavage fibres*, by far the most common of all, which occur in inflammatory exudations after coagulation; 2. *Fibres of coagulation*, *i.e.* formed by fibrillation of fibrine, as occurs in colloid; 3. *Cell-fibres*, those formed in cells (Fig. 50); 4. *Nuclear fibres*, those formed of elongated nuclei (Figs. 51 and 174).

The first two forms seem identical with simple fibres. Nuclear fibres are the embryonic form of the yellow fibrous tissue.

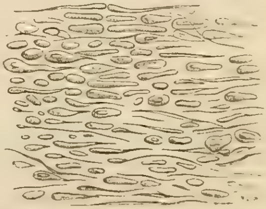
Fig. 50.

Fibre-cells passing into fibres.

Fig. 51.

Nuclear fibres.

Fig. 52.



Simple fibres and nuclei in false membrane.

[1] The elastic spiral fibre in the tracheæ of insects is probably mere simple fibre; and the fibre found in the air-vessels of plants presents a similar appearance, though of different chemical composition.

That fibres of any kind are ever formed by the mere conjunction of nuclei, must be, for the present, regarded as very improbable. Simple fibres are found as a permanent development in some false membranes, so called, as shown by Fig. 52.

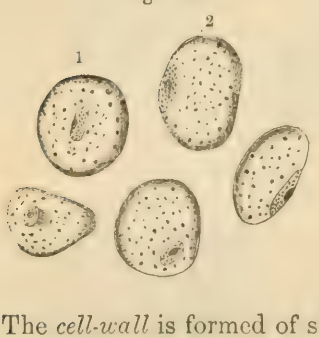
CHAPTER IV.

CYTOLOGY.—CELLS.

THE description of the cells (and their development and function), from which the tissues are originally formed, constitutes the department of histology termed Cytology.[1] These are closed vesicles, usually of a globular form, varying from $\frac{1}{120}$ to $\frac{1}{6000}$ of an inch in diameter, and consist of the five following structural elements:—

1. The cell-wall.
2. A contained fluid.
3. Granules floating in the fluid.
4. A nucleus.
5. A nucleolus.

Fig. 53.



Cells showing the cell-membrane, the contained granules, the nucleus, and the nucleolus. 1 and 2. The typical spherical form. The rest as changed by pressure.

1. The *cell-wall* is formed of simple membrane, and, of course, is an albuminous compound, but is not fibrine. Though varying much in thickness in different instances, it presents nothing peculiar. It is generally soluble by acetic acid. The walls of epithelial cells, however, are not thus dissolved after they become corneous, though

[1] From κύτος, a cavity or cell, and λογος, description.

they are while young; and the same is true of most pathological cells. The wall of the colored blood-corpuscle is not dissolved by acetic acid; but most observers regard these bodies as nuclei, and not as cells.

2. The *fluid* contained in the cells is almost invariably transparent, or nearly so. In the blood-corpuscles, however, it is of a bright red color. In chemical composition it varies extremely, being usually an albuminous compound—in part, at least. It is not so, however, in the epithelial cells of glands; and in the cells of adipose tissue it consists of margarine and stearine dissolved in oleine (p. 76.) The cells of the epidermis, and of nails, horn, and hoofs, contain keratine and fat; and those of the epithelium on mucous membranes generally contain mucosine, but no albumen.

3. The *granules* floating in the fluid contained in the cells are often in immense number; are rounded corpuscles, so minute as hardly to admit of being measured; and, in most instances, have no investing membrane. This is the case with the fatty granules in many cells and glandular secretions,[1] they being merely fat-globules. The granules giving the color to the pigment-cells have also no investing membrane.

In other cases the granules have an investment, and are termed elementary vesicles (more properly called *free nuclei*); *e. g.* milk-globules are originally such granules of fat, with an investment of caseine in the form of a simple membrane (p. 89), and contained within the secreting cells; and the molecules floating in chyle and blood are mere fat-granules with an albuminous investment. (*Müller.*[2])

T. Wharton Jones regards the colored blood-corpuscles of man and the mammalia as elementary vesicles, or free nuclei, except while in the parent cells (the colorless corpuscles of the blood) in which they were formed. Neither of these two kinds of floating granules just mentioned (milk-globules and blood-corpuscles) increase in size when once formed, nor do they multiply by subdi-

[1] As the granular precipitates of the coloring matter of the bile. Add to these, also, the *albuminous* granules in certain portions of the gray substance of the cerebro-spinal centre, and of the retina.

[2] Ascherson discovered, in 1840, that whenever fluid fat and fluid albumen are shaken together, the fat-globules thus formed are always surrounded by an albuminous coat. He termed this the *haptogen* membrane. It is the result of mere chemical action, and exhibits no vital endowment whatever.

vision or by endogenous development. (*Kölliker*, p. 12.) Thus they incline towards merely inorganic forms, as produced by crystallization.

It should be added that in some cells no granules exist, but only a clear fluid, as in case of the fat-cells and the colored blood-corpuscles.

4. The *nucleus* is a globular or lenticular body, measuring from $\frac{1}{6000}$ to $\frac{1}{3000}$ of an inch.[1] It is attached to, or imbedded in, the wall of the cell, except in case of the free nuclei already mentioned, which have escaped from the parent cell, and have no nucleoli; and is transparent and of a yellowish color. All nuclei are themselves vesicles. The contents are, besides a nucleolus usually present, almost invariably a yellowish or transparent fluid; and in this both water and acetic acid precipitate the same dark granules which are found floating in the cells.

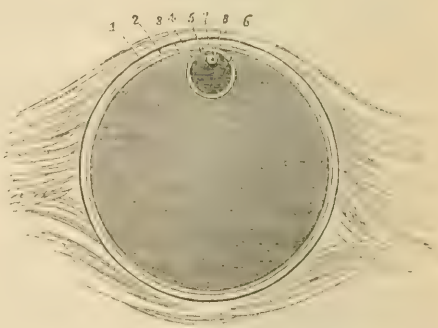
Acetic acid, however, renders the nucleus more visible, while it dissolves the cell-wall. But the *pus-corpuscle*, which Gluge incorrectly regards as a mere nucleus, is dissolved by this acid.

Sometimes this vesicle (the nucleus) contains formed granules, as the spermatic filaments (spermatozoids) in semen (Fig. 54), and peculiar granules (germinal spots) in ova (Fig. 55). The germinal spot is actually a *nucleolus* within the germinal vesicle, the latter being the nucleus of the ovum.

Fig. 54.

Spermatozoids. 1 to 4. Their variety in form. 5. Seminal granules.

Fig. 55.



Germinal spot, &c., of ovum 1. Stroma of the ovary. 2 and 3. External and internal tunics of the Graafian vesicle. 4. Cavity of the latter. 5. Thick tunic of the ovum, or yolk-sac. 6. The yolk. 7. The germinal vesicle. 8. The germinal spot.

[1] It sometimes measures even from $\frac{1}{1200}$ to $\frac{1}{500}$ of an inch, as in ganglion-cells and ova.

The membranous wall of the nuclei is certainly an albuminous compound, and probably but little, if at all, different from the younger cell-membranes. Generally the granules within it are mere globules of fat, like those floating in the cell.

Nuclei are found in all cells of embryos, and in adults also while the cells are still young; though in some cases, as in the fat-cell, they subsequently disappear.

Generally but a single nucleus exists in each cell; but when a cell is multiplying, as many nuclei arise as there are new cells to be formed.

In some cases, however, several nuclei naturally exist; four, ten, twenty, or even more, nuclei being found in the same cell. This is especially the case with cancerous and other rapidly developed malignant growths.

Free nuclei also take part in the formation of certain tissues—as in the rust-colored layer of the cerebellum, and in the granular layer of the retina.

Thus a nucleus is, histologically, an embryo cell.

Pathological Developments of Nuclei.

1. The characteristic structure of *tubercle*—tubercle-corpuscles—consists of mere *nuclei* inclosing nucleoli, there being no cells in this deposit. The other element of tubercle is an amorphous, semi-solid hyaline substance, which, in the opaque or yellow variety, but not in the gray or transparent tubercle, contains granules also (p. 108).

The nuclear bodies of tubercle are usually oblong, polyhedral, averaging $\frac{1}{3571}$ of an inch long, and $\frac{1}{4545}$ of an inch wide. They consist (1) of a delicate transparent membrane, with (2) a transparent, colorless, or faintly ambreous fluid, containing (3) granules, and

Fig. 56.

Fig. 57.

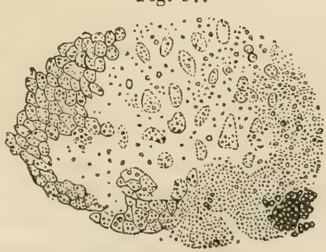


Fig. 58.

Fig. 56. Tubercle-corpuscles from peritoneum. Those at the right show the effects of acetic acid. Fig. 57. Tubercle-corpuscles and granular homogeneous substance from lung. Fig. 58. Tubercle-corpuscles from mesenteric gland. Free oil-globules are seen at the right in Fig. 57.

(4) two or three to a dozen scattered, globular, transparent nucleoli. (Figs. 56, 57, and 58.)

Tubercle-corpuscles are distinguished from those of pus, from being smaller, less granular, and not having their nucleoli aggregated. Acetic acid also slightly affects their nucleoli; while it must often be applied to the nucleoli of pus-corpuscles, to render them visible. The peculiar nuclei of *cancer* are distinguished from those of tubercle by being larger, regularly oval, or not unfrequently spherical, and from containing only one or two nucleoli.

As seen under the microscope, typhous and scrofulous deposits are not to be distinguished from tubercle.

Chemical analysis of the solid matter of tubercle gives the following result. (*Preuss.*) Scherer, however, finds that tubercle varies much in composition in different cases.

1. *Matters soluble in hot alcohol.*	
Cholesterine	4.94
2. *Matters soluble in cold alcohol, but not in water.*	
Oleate of soda	13.50
3. *Matters soluble in dilute alcohol.*	
A peculiar substance Lactate and sulphate of soda Chloride of sodium	8.46
4. *Matters soluble in water.*	
Caseine[1] Sulphate and phosphate of soda Chloride of sodium	7.90
5. *Matters insoluble in cold water and alcohol.*	
Caseine[1] altered by heat Phosphate and carbonate of lime Oxide of iron, magnesia, and sulphur	65.11
	99.91

In cretaceous transformation of tubercles, the salts of lime especially become increased. The small amount of fat existing in tubercle has already been alluded to (p. 78). In a gray, well-dried tubercular mass, Lehmann found but 3.54 per cent. of fat. The cholesterine should not be regarded as fat.

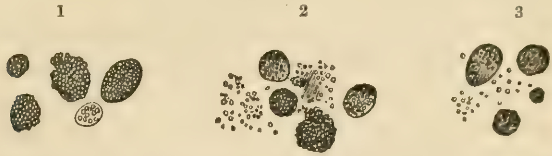
2. The *exudation-corpuscle* (inflammation-corpuscle of Gluge) consists of a group of ten to forty or more granules, held together by a coagulated albuminous matter, soluble in acetic acid. These mulberry-like bodies are also called granule-cells and *glomeruli.*

They measure from $\frac{1}{2400}$ to $\frac{1}{960}$ of an inch in diameter. They

[1] An albuminous compound, but not caseine. (*Lehmann.*)

are, however, not peculiar to inflammation, but appear in the colostrum and in the egg. They are regarded as free nuclei, and are represented by Fig. 59.

Fig. 59.



Glomeruli and granular cells. The dark cells are the glomeruli. 1. From inflamed lung. 2. From inflamed pia mater. 3. From tubercular meningitis.

5. The *nucleolus* is a round, sharply defined, fat-like granule, generally of a dark color, and measuring $\frac{1}{12000}$ to $\frac{1}{9000}$ of an inch[1] in diameter. It is inferred that they are vesicular, from their sharply defined form, from their similarity to free nuclei, and from the fact that, when large, a cavity filled with fluid frequently becomes developed in them. Acetic acid does not dissolve them.

They are believed to be constituted of fat, with an albuminous compound for the investing membrane.

Nucleoli are generally found in nuclei while still young, and in many during their whole existence. Still, they cannot be regarded as an essential constituent of the cell, like the nucleus, since they cannot always be with certainty recognized in the latter. Cells without nuclei, of course, have no nucleoli.

Usually but one nucleolus is found in a nucleus, but frequently there are two; and in solitary cases four or five may be found, which then are either eccentric, or lie free in the nucleus.

A nucleolus is, therefore, histologically, an undeveloped nucleus; and since both nucleoli and nuclei contain fat, and the free granules in cells consist of it usually, in part at least, fat is always indispensable in the plasma from which cells are developed. On the other hand, there is no evidence that *fibrine* exists in the cell-wall or the contained fluid. All agree that the former is an albuminous substance.

That fibrine, therefore, is the only plastic element in the blood, is highly improbable. The remark of Gluge, that "the formation of fibres and cells from fibrine is a matter of direct observation,"[2]

[1] In ganglion-cells, and in the germinal spots of ova, they sometimes measure $\frac{1}{4000}$ to $\frac{1}{1200}$ of an inch.

[2] Pathological Histology, p. 50.

might seem to settle this question otherwise; but it apparently does not occur to this observer that the plasma under his microscope is not fibrine alone, but the liquor sanguinis, and therefore only about $\frac{1}{250}$ part fibrine.

Hence, while the formation of fibres and cells is a matter of direct observation, the assertion that cells are formed from fibrine is a mere assumption, which we cannot accept even on this high authority without proof. This, up to the present time, is entirely wanting. All the facts hitherto presented point, on the other hand, to the inference that the albumen of the blood, and not the fibrine, is the *pabulum* of the cells whose structure and composition have just been specified. (See also pp. 86 and 91.)

Development of Cells (*Cytogeny*[1]).

Cells are developed in two ways—

I. Directly from the plasma (p. 95, X.), without the aid of a pre-existing cell: *free* cell-development.

II. From other cells.

A. Within them: endogenous cell-development.

B. By their *subdivision* into two or more cells: *fissiparous* cell-development.

I. *Free Cell-development.*

Free cell-development occurs in the case of the chyle and lymph-corpuscles, of the cells of certain glandular secretions, of the spermatic cells, of ova, the cells in the closed follicles of the intestine and of the lymphatic glands, and in the corpuscles and pulp of the spleen.

The nucleus[2] of a cell is always, according to most observers, the part first developed. Granules first appear in the clear plasma, some of which increase in size, and assume the form of a minute vesicle, the nucleus of the future cell. On the addition of water to this, granules become apparent in its interior, and one of these, larger than the rest, appears to be the nucleolus. *Around* the nu-

[1] From κύτος, a cell, and γένος, descent, production.

[2] Hence the nucleus is sometimes termed a *cytoblast*—*i. e.* a cell-germ—from κύτος, cell, and βλαστὸς, a germ or shoot.

The word *cytoblastema* is also applied to the fluid in and from which the cells are formed. *Blastema* means the materials from which germs are developed.

cleus, as is generally stated, the cell-membrane is developed, and thus the cell is completed.

But, admitting the preceding account to be correct in particular cases, another explanation of the process certainly applies in some, and, it is believed, in most instances. It is thus expressed by Dr. Burnett as being usual in animal tissues, at least:—

1. A primordial utricle appears in the clear plasma.
2. It expands into a clearly seen vesicle.
3. A partial condensation occurs of its liquid contents towards the centre, giving rise to a new utricle, constituting the nucleus; the whole thus forming the complete nucleated cell.[1]

When we consider that the nucleus, the nucleolus, and the primary utricle are all vesicles, or minute cells already formed, we may well admit that either the utricle or the nucleus may be first formed, and in time become a larger cell; and it still admits of question whether, in the last instance, the cell is not formed by mere enlargement of the nucleus, instead of *around* it. But, doubtless, a cell, while being developed, may also develop a nucleus within it, precisely as a nucleus develops within itself a nucleolus.

The most satisfactory view of the subject appears to be the following; it being understood that only those cells are now under consideration which are formed in a clear plasma, and not those formed from other cells.

No sufficient reason appears why a primary utricle may not be, in all cases, as easily formed in a clear plasma as a nucleus can; and if this becomes a cell in one instance, and then forms a nucleus *within* itself, it is hardly probable that a nucleus, on the other hand, is first formed in other instances, and then forms a cell *around* itself. It is far more probable that the first cells are formed in a clear plasma without the aid of a nucleus, they being merely fully developed primary utricles; true *free cell*-formation always proceeding in this way. The second generation of cells may be formed from the nuclei in the first, or not; but, if so, it is endogenous formation, and not the form of development here under consideration. If all the cells of any given kind are to be formed by free cell-development, however (as the chyle-corpuscles), then we see no advantage at all in their containing nuclei. The fact that any cell contains a nucleus evinces a power of producing another cell by endogenous

[1] Prize Essay, Transactions of the American Medical Association, vol. vi. p. 861.

formation; though here, also, it may still be a question whether the nucleus itself becomes the future cell, or whether it forms the new cell around itself, as is generally asserted.[1]

If, in any case, but a single generation of cells is required, for the reason that the original ones are to remain unchanged in the organism, no nuclei are, of course, needed, *if* we still maintain that the nucleus exists merely to develop another cell. Some have placed the fat-cells in this category, though incorrectly, as will appear. (Chap. V.)

In the ovum alone (so far as is known) a layer of semi-solid plasma is interposed between the nucleus and the cell-membrane, and entirely incloses the former. (Fig. 55.)

In *pathological* productions, free cell-development is very common. Pus-cells and exudation-cells (or corpuscles) are thus formed. This method of development of epithelial cells, and of those of which nails and horn are formed, is, however, rather assumed by authors than established by proof.

II. *Development of Cells from pre-existing Cells.*

A. *Endogenous Cell-development.*

The most frequent form of endogenous cell-development is that in which two secondary cells are produced within the original one. Here, in the first place, the nucleus of the parent cell enlarges, and exhibits two nucleoli; then it becomes elongated, and constricted in the middle, and at last separates into two portions. Each of these becomes the nucleus of a new cell, and the two nucleated cells thus formed at length fill up the interior of the parent cell. (Figs. 60 and 61.) The parent cell may burst and set free the secondary cells, or continue to enlarge till several generations have been thus developed within it. On the other hand, it may coalesce with the substance which unites the cells as a matrix.

This mode of development in persistent parent cells[2] occurs in the cartilages of all young animals, and very probably during the development of the tissues generally, in their embryonic state. (*Köl.*)

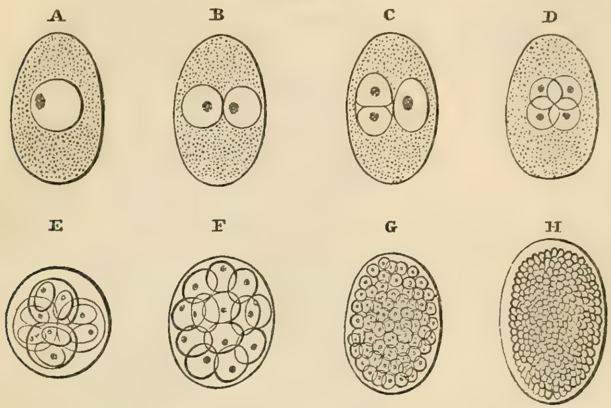
Thus the nucleus existing in a cell is the germ which is to be developed into the cell of the next generation—that of which the

[1] The blind adherence hitherto to the observations upon cell-development, of Schwann and Schleiden, has retarded the progress of histological science, and the whole subject demands investigation *de novo*.

[2] *Cavities*, rather. See Chap. VI.

first is the parent; while the nucleolus bears the same relation to the nucleus that the last does to the original cell, *i. e.* it is to be de-

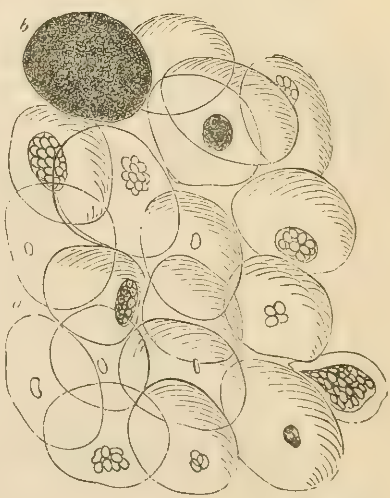
Fig. 60.



Endogenous cell-development. A, B, C, D. Early stages of the process (ovum of *Ascaris dentata*). E, F, G, H. More advanced stages (ovum of *Cucullanus elegans*).

veloped into the third generation—the cell of which the second is the parent. While the nucleus is forming, it develops within itself the nucleolus; and while it is becoming the second-generation cell, the nucleolus becomes a nucleus, and, in its turn, forms a nucleolus within itself. Thus the nucleus itself becomes the next cell, though it is not here asserted that it in no case forms a cell *around* itself. Hence, also, if a cell has never contained a nucleus, it is itself called a *free nucleus*, as we have seen, or an elementary vesicle. It is not, physiologically, a cell, and has no power of multiplication. Such are the corpuscles of tubercle, and the colored corpuscles of the blood (p. 115). These may or may not contain nu-

Fig. 61.

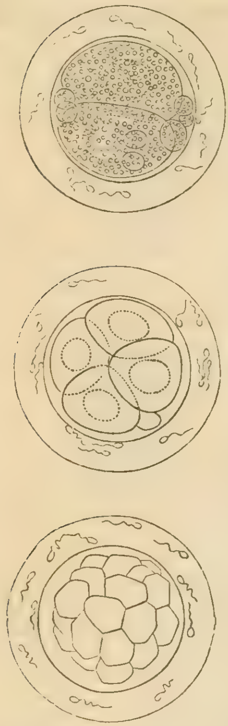


Endogenous cell-growth (meliceritious tumor). *a*. Cells with nuclei variously developed. *b*. Parent cell filled with young cells, which have originated from the granules of the nucleus.

Fig. 62.

A

B



Segmentation of the vitellus (yolk) of the mammalian ovum. A. Its first division into two halves. B. Subdivision of each half into two. C. Further subdivision, producing numerous segments.

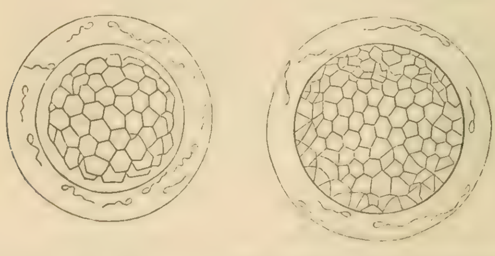
cleoli, and are developed either in a plasma or within pre-existing cells.

In the fecundated ovum the formation of cells is preceded by a peculiar process—the cleavage or segmentation of the yolk—which is introductory to an endogenous cell-development. The nucleus of the parent cell (*i. e.* the germinal vesicle), Fig. 55, disappears after fecundation, and the granules become dispersed and fill the whole cell. Another nucleus is then developed around a nucleolus, and the yolk forming around it, in a globular form, constitutes the first cleavage-mass. From this nucleus two others are formed, as before described, and then two cleavage-masses result; and thus the multiplication proceeds till the cavity of the yolk is filled with small globules. Lastly, the latter, either together or in successive layers, are surrounded with investing membranes, and thus become perfect cells—the parent cell still persisting, and inclosing them. Figs. 62 and 63 illustrate this process, and also show spermatozoids on the outer surface of the vitellus or yolk.

Generally, the development of a large number of cells within a single parent cell occurs only in structures of a rapid growth,

Fig. 63.

A B



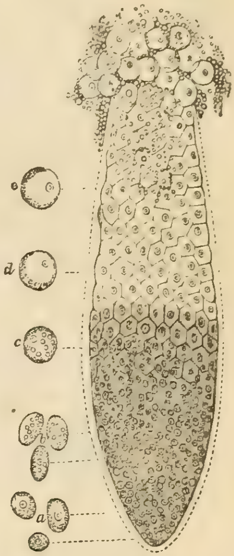
Segmentation of the yolk—latter stages. A. The "mulberry-mass" from the minute subdivision of the vitelline spheres. At B it has come into contact with the vitelline membrane, against which the spherules are flattened.

which do not form a permanent part of the organism; such as granulations and cancerous or other malignant growths which undergo a speedy degeneration. (Fig. 64.)

Fig. 64.

Cells (and fibres) from encephaloid of tongue, growing rapidly.

Fig. 65.



One of the hepatic cœca of the cray-fish (*Astacus affinis*), showing the progressive development of the secreting cells from the nuclei at its bottom. The stages are shown by the letters *a* to *e*.

The vital force is, as it were, exhausted by this rapid multiplication, so that the cells thus formed are incapable of further development, while the slow method by duplication may proceed to any extent. In glandular follicles, however, this rapid multiplication of cells "may often be recognized," for each of the terminal cœca or follicles is regarded as a single parent cell with a persistent nucleus (germinal centre); and it appears that the materials of secretion are eliminated from the blood by the continual development of young cells from this nucleus. (Fig. 65.)

B. *Fissiparous Cell-development, or that by Division.*

In the multiplication of cells by division, the original cell first becomes elongated, and two nuclei are developed from the original nucleus, by division, apparently, as before described. The cell then becomes constricted at the middle, and, the nuclei receding from

each other, it finally separates into two distinct nucleolated cells. In the blood-corpuscles of the chick, all the stages of this process can be readily observed.

Fig. 66.

Blood-corpuscles multiplying by bipartite division. (*Kölliker.*)

This development of cells by bipartite division occurs in the red blood-corpuscles of the embryos of birds and mammalia, and in the first colorless corpuscles of the tadpole. (Fig. 66.) It also occurs, probably, in the colorless blood-corpuscles of the human embryo, and, sometimes at least, in the chyle-corpuscles of adult animals. (*Kölliker.*)

It is also constantly observable in the development of cartilage (Figs. 67 and 46), and here the division may be bipartite, tripartite, or even tetrapartite.

Fig. 67.

Multiplication of cartilage-cells by division.

The Physiology of Cells.

Under this head will be considered—

A. The growth of cells.

B. Their physiology proper, including the nature of their contents, and the processes performed by them.

A. *The Growth of Cells.*

Growth, doubtless, occurs in all cells, to some extent. It is, however, most manifest in cases when the cell-membrane is formed

directly around the nucleus. But cells which from the first have contents (the cell-membrane in these cases forming around masses investing the nucleus), increase very slightly in size.

The nucleus, and nucleolus also, usually increase in size with the cell; but the nucleoli always retain their globular form, except when dividing fissiparously.

In cell-growth there is an increase either of the surface or of the thickness of the cell-wall, and this increase may be either general or partial. It is general when the cell grows larger without change of form;[1] partial when the cell changes its form by extending itself at two or more points. Carpenter thinks this extension takes place in the direction of the least resistance; but its cause is not demonstrated. In some cases the cell becomes narrower as it elongates; and here we must admit that absorption occurs in one direction while deposition goes on in the other.

The power of growth does not appear to be simply innate in every organic membrane, and therefore manifesting itself whenever formative material is presented, but it requires certain conditions which the cell-membrane alone affords. The nuclei, when free, never grow to any considerable extent, and especially not in one particular direction.[2]

B. *The Nature of the Contents, and the Functions of Cells.*

Usually the *contents* of a cell may be regarded as a "moderately concentrated solution of albuminous elements with alkaline and earthy salts, and dissolved or suspended fatty particles." Different cells, however, differ greatly in this respect; some one of these constituents greatly predominating in some, while in others altogether different substances may be found. The nerve-cells abound in albuminous elements; adipose cells, and those of the sebaceous follicles and of milk-glands, in fat; while in certain other cells, hæmatine, melanine, or biliary or urinary constituents, abound.

The *functions* performed by cells, as inferred from the phenomena manifested by their contents, may be specified under the heads of

[1] According to Schwann, the cell-membrane exerts an attractive influence upon the surrounding fluid, and causes the deposition of newly formed particles in its substance; and partial growth occurs when the molecules do not all attract equally, but only, or more particularly, at certain points.

[2] The nuclei in the hair-pulp, tooth-pulp, areolar tissue, and smooth muscular fibre, however, grow in one direction, to a considerable extent, these not being free.

absorption, *secretion*, and *contraction*. These vital actions depend much on physical and chemical conditions, and may, to a great extent, be subjected to microscopic investigation.

1. *Absorption* must be distinguished from mere endosmosis, since the nutrition of the cell (a vital and not a mere physical process), depends on the former, and some of the constituents of the surrounding fluid are introduced through the cell-membrane, while the rest are rejected. Thus the contents of all cells are chemically different from the surrounding cytoblastema. For instance, the blood-corpuscles contain more potassa than the liquor sanguinis. Doubtless the chemical composition of the cell-contents and the surrounding fluid, and the thickness of the cell-membrane, also exert an influence on this process; nor must endosmosis be entirely overlooked in this connection, since cells are known to dilate in diluted, and to contract in concentrated solutions.

The vital processes in cells produce changes both in their walls and in their contents. The *membranes* generally become denser, and of a different chemical constitution, with age; though whether the membrane itself changes chemically, or an incrustation of salts occurs within, or a deposit on the exterior, are points not conclusively settled.

The changes in the cell-*contents* are various. The primordial cells of the embryo, at first distended with the elements of the yolk, especially with oil, gradually acquire more fluid and homogeneous contents, the granules becoming dissolved. Then, as development proceeds, various new formations appear in the cells, as hæmatine, melanine, fat, &c. But changes in cell-contents occur in adult animals also. Fat-cells, in great deficiency of their nutritive elements, may lose their proper contents, and contain mere serum; or, in case of a superfluity of nutriment, they may even burst from fulness.[1] The lymph-corpuscles also develop the coloring matter of the blood and the colored corpuscles, within them; and the cells which secrete the bile undergo marked changes in their contents. (*Kölliker.*)

Changes in the *form* of the cells accompany the preceding altera-

[1] Donders has ascertained that the cell-membranes are elastic, and the contents will suffer a greater or a less pressure, according to their amount. This elasticity may conduce to the maintenance of a regular interchange of substances in the excretive and absorptive processes. And the greater density of the cell-contents than of the surrounding cytoblastema may be due to the fact that they are always under greater pressure.

tions in the contents, such as thickening of the membrane with laminated depositions, as in cartilage, and with the formation of minute canals; while within, also, the granules may be precipitated, fat-drops, elementary vesicles, concretions, crystals, or nuclei may be formed, and molecular movements may occur.

The *nuclei* rarely participate in these changes, though they sometimes become clear in consequence of the liquefaction of their viscid contents. Very rarely granules are developed in them; and in certain animals, "urticating threads" and spermatozoids are developed in nuclei.[1]

2. The process of *secretion* is manifested by cells in two ways:—

First. Their contents consist of substances received from without, unaltered, or slightly so; as in case of epithelium-cells, especially of serous membranes, and the cells of those glands which simply separate certain substances from the blood—*e. g.* the lachrymal glands and the kidneys. (*Kölliker.*)

Secondly. The cell-contents include substances prepared within the cell; as the colored blood-corpuscles, fat-cells, the bile-cells in the liver, and those (secreting the gastric fluid) of the gastric glands.

3. *Contraction* is sometimes manifested by cell-membranes and by the cell-contents. *Contractile cell-membranes* occur in many, if not all, of the Protozoa, in the yolk-cells of the Planariæ, in the heart-cells of many embryos, &c. Some consider that the colorless corpuscles of man, the frog, and the skate, mucus-corpuscles, and the cells in the meshes of the areolar tissue of the disk of the medusa, are contractile cells.[2]

Contractile cell-contents are found in the fibre-cells of smooth muscle, in the stellate cells of the skin of the embryo limax, and in striped muscular fibre.

Certain important changes in the cell-contents occur in pathological conditions. Besides those already specified, the following may be noted here:—

1. *Fatty degeneration* is the most common change in cell-contents, more or less fat-drops accumulating in the cell. But it must be borne in mind that the cells in certain parts and organs normally contain a few fat-globules.

[1] Thus it is very certain that the molecular and chemical changes of the cell-membrane and the nucleus are independent of each other.

[2] Donders, however, maintains that the cell-contents only (and not the cell-membrane) are contractile.

2. The fatty degeneration may pass into the *pigmentary;* which may also occur spontaneously. Here the coloring matter generally passes from deep yellow to brownish black.

3. *Dropsy* of cells occurs if the blood contains an undue amount of water. (*Wedl.*)

4. *Crystals* form in cells from the absorption of the watery portion of the cell-contents.

5. *Atrophy* or involution (*Wedl*) of cells may occur, in consequence of a diminished supply of nutrient fluid.

Primordial Cells.

Schwann discovered that all the tissues of animals,[1] as well as of plants, are developed originally from nucleated cells; and to these the name of primordial cells has been given. They present nothing peculiar in their microscopic appearance, however; containing the five elements already mentioned as usually characterizing a cell (p. 114). We find in the embryo a mass of cells, for instance, which are to develop bone; another to form muscle; a third, fibrous tissue, &c. But though the microscope does not enable us to detect any original difference in them, their vital properties must differ, as the developmental result demonstrates.

Schwann's assertion, however, applies only to the tissues proper, and not to the simple histological elements already described. Simple fibre and simple membrane are, for example, lower developments than cells, and are not formed from the latter. On the contrary, cells have their walls formed of simple membrane, as has been shown.

The primordial cells, therefore, need no further notice here, since it is in respect to their functions, and not as mere histological elements, that they are peculiar. Besides, the manner in which each tissue is developed from its primordial cells, and the peculiarities of the latter in each case, will be explained in the division of this work upon the "Tissues proper."

Before proceeding to speak of the fluids, however, certain cells which are either found isolated, or, at least, do not coalesce to form tissues, will be described.

[1] This discovery was announced in 1839. Schleiden had previously shown that the tissues of plants are formed from cells.

Isolated Cells: Cells not coalescing to form Tissues.

Under the head of isolated cells, Carpenter includes the white and the colored blood-corpuscles, epidermis and epithelium, the cells containing the spermatozoids of the semen, and absorbing and secreting cells.

Epidermis and epithelium, however, perform their functions as a distinct tissue, and will therefore be included in the classification of the tissues proper. Secreting cells will be described in connection with the various glands containing them; and the blood-cells of both kinds, and the spermatophori, will be considered in connection with the fluids of which they respectively constitute a part.

The only kind of cells to be considered here, as being normally scattered in the interstices of the tissues, and not forming a tissue by themselves, is the *pigment-cell;* after which the various forms of cancer-cells will be described, as constituting one of the most important of the pathological developments.

The isolated cells in the nervous centres will be described in the chapter on "Nerve-tissue."

I. Pigment-cells.

Pigment-cells derive their peculiarities from the fact that the granules they contain are colored, consisting of the immediate principle melanine, described on page 103. As this principle abounds in carbon, neither chlorine nor strong acids remove the color of the granules. The latter are often found lying among the cells, as well as within them. They are also among the minutest objects in nature, being often less than $\frac{1}{30000}$ of an inch in diameter.

It has been shown that melanine is probably derived from hæmatine, and, like the latter, has iron associated with it; the pigment of the choroid coat of the eye containing .254 per cent. of this metal.

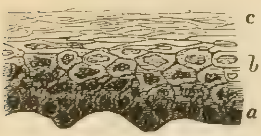
Distribution of Pigment cells.

In the human body, the distribution of pigment-cells is quite limited. In the eye, they are found on the inner surface of the choroid membrane, on the ciliary processes and the iris (uvea), and between the choroid and the sclerotica. They also exist in the skin of the perineum and of the genital organs, especially of the scrotum, and in the areola of the mammary gland. Pigment-granules also

give the gray color to the cells of the cortical substance of the cerebrum and cerebellum, and the central part of each half of the spinal cord; and pigment-cells are also found in the cervical pia mater and the membranous labyrinth.

In negroes, the skin also contains a layer of pigment-cells over the whole surface of the body; and to this its blackness is due. This is the last formed and deepest layer, consisting of cells lying directly on the basement membrane of the skin. Similar cells, darker than the rest, also exist in this layer of the skin of Europeans, but their pigment is of a lighter color. In fact, the difference in amount and color of pigment in this layer of cells gives rise to all the varieties of color presented by the different races of men. Fig. 68 represents the appearance of the several layers of cells in the cuticle of the negro. In the outer layers, which are flattened into scales, the pigment is entirely absent. If the cuticle of the negro be removed by a blister, the pigment-cells on its inner surface will be found clustered together around circular spots of a bright color where the cells are wanting. The spots correspond to the depressions in the under surface of the cuticle into which the papillæ of the skin projected. On the other hand, in albinoes[1] no pigment-granules are found in the epidermis at all.

Fig. 68.



Section of the cuticle of the negro. *a.* Deep cells, loaded with pigment. *b.* Cells at a higher level, paler and more flattened. *c* Cells at the surface, scaly and colorless, as in the white races.

Freckles upon the skin of the white races, whether congenital or otherwise, are also due to a development of pigment cells in the layer next underneath the epidermis—the Malpighian stratum.

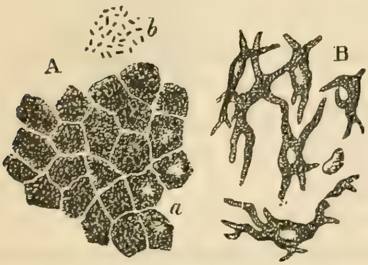
The pigment in the lungs of man and the lower animals, both under the pleura and in the parenchyma, is in the form of granules; but which are not contained within cells. They are probably mere particles of carbon. In the lower animals, a single lobe is sometimes quite black, while the rest remains unchanged; though a section of it shows that its function is not essentially, if at all, impaired by the deposit.

[1] So called from *albus*, white.

Peculiarities of Form of Pigment-cells.

Generally, pigment-cells present no peculiarities of form; but those (the pigmentum nigrum) of the choroid membrane of the eye are of a hexagonal form, resembling pavement epithelium. (Fig. 69.) Those between the choroid and the sclerotica are somewhat

Fig. 69.



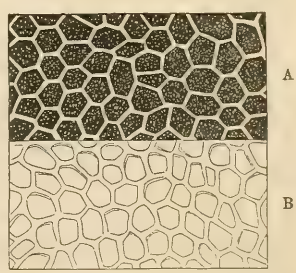
Pigmentum nigrum of adult human subject. A. Cells forming epithelium of the choroid. B. Irregular cells from substance of choroid. Nuclei visible at *a*; pigment granules, *b*.

Fig. 70.

Cells between the choroid and sclerotic of the sheep. (*Queckett.*)

fusiform, and sometimes have bifid extremities. Their appearance, as found in the sheep, is shown by Fig. 70. In both these figures the nuclei are seen to be white. In albinoes there are no pigment-granules in the cells on the choroid, and hence they are not *pigment*-cells. Fig. 71 shows the appearance of the cells of the pigmentum nigrum of a black rabbit at A, and of the white (albino) rabbit at B. In the human fœtus, also, the granules are less numerous than in the adult. The pigment-cells of the human skin also often present the hexagonal form; they being here, in fact, epithelial (epidermic) cells.

Fig. 71.

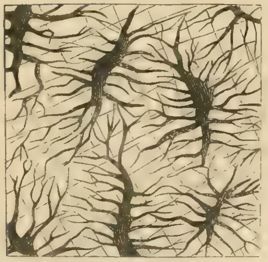


A. Cells on choroid of black rabbit. B. Cells on choroid of white rabbit, destitute of pigment granules. (*Queckett.*)

Distribution of Pigment-cells in the Lower Animals.

In the *lower animals*, pigment-cells present a variety of forms. In the skin of the lamprey they resemble the lacunæ and pores of bone. (Fig. 72.) In the skin of the frog, and some other reptiles, they are of a more stellate form. (Fig. 73.) In the iris of the tiger

Fig. 72.



Pigment-cells of the skin of the lamprey. (*Queckett.*)

Fig. 73.

Pigment-cells in tail of the tadpole. The transparent ones are the young cells, in which the pigment granules have not yet appeared.

boa (*Python tigris*), white pigment-cells are found. (*Queckett.*) The red spots on the skin of the plaice are produced by minute, irregular cells. Pigment-cells are often found in the peritoneum of fishes and reptiles; and the pigment secreted in its ink-bag, so called, by the cuttle-fish, is used by artists under the name of "sepia."

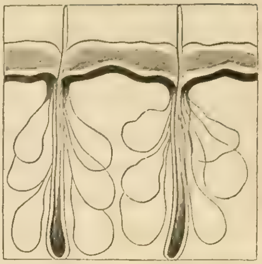
Color of the Hair and Eyes.

In connection with the color of the skin, that of the hair and eyes should be alluded to; though the coloring matter may be otherwise than black in case of either, and therefore is not always melanine.

The pigment coloring the hair is found generally both in the cortical and in the medullary portions of the shaft; and since hair is an epithelial appendage, as will be shown, we might expect that its color will correspond, within certain limits, with that of the skin. Spots of black hair are found (as in the hog) to grow on patches of skin of the same color. In the albino, on the other hand, the hair is colorless. For the particulars, however, consult the section on "The Hair."

The color of the *eye* is determined by that of the iris, as is explained in the last chapter of this work. It is blue, hazel, and, in some cases, nearly jet black. The conformity of color with that of the skin (or the complexion) is not so rigid as is that of the hair; and yet the disparity ranges within certain limits. The irides of albinoes are of a pink color; since, not being covered with pigment-cells, the numerous very minute bloodvessels of the iris are visible.

Fig. 74.



Section of skin of the nose, showing pigment. (*Queckett.*)

The sebaceous follicles of the skin being in close relation with the hair-bulbs, are sometimes found distended with pigment. This is especially the case in *acne*, a disease essentially consisting of an enlargement and suppuration of the sebaceous follicles, and in which masses of black matter may be pressed from them. Fig. 74 shows a section of the skin of the nose having a stratum of black pigment in the deepest portion of the cuticle, which also dips down into the sebaceous follicles, seen on each side of the two hairs growing from the corium.

Development of Pigment-cells.

The stimulus of solar light doubtless exerts an influence on the development of the pigment-granules. In many persons a strong sunlight produces freckles; and exposure for several years to a tropical climate renders the fairest complexion sallow. The Dutch who have for several generations resided in Africa, have at length become so black as to be distinguished from the natives by their features only, and not by their color. The natives of the torrid zone almost invariably have black hair and eyes. The infant negro is scarcely darker than the white during the first few days after birth.[1] The genital organs become colored on the third day, and the whole body on the fifth and sixth.

The stimulus of solar light is essential to the development of the green pigment (chlorophyl) of plants, which also consists, in great part, of carbon; and with this fact the preceding may be naturally associated.

Functions of Pigment-cells.

The pigment-cells in the pigmentum nigrum of the eye are important principally in the way of interrupting or absorbing light, and thus contributing to the perfection of vision. Hence albinoes cannot see well in the full light of a sunny day. In the substance and on the posterior surface of the iris, however, the pigment-cells

[1] Some writers maintain that the different varieties of the human race are due to climatic influences, exerted through a long succession of generations. If *color alone* were to be taken into the account, this idea would be more plausible.

seem to be intended, at the same time, for ornament also—giving the peculiar color to the eye. The variously colored cells on the surface of the lower animals apparently subserve the latter object alone. We cannot, however, remark the same in regard to the colored spots on the peritoneum of some of them.

The presence of pigment-cells in the epithelium of the skin of man bears some relation to the degree of solar light and heat to which it is exposed; but which is not well understood.

Pigment-cells abound, as has been stated, in the human brain and spinal cord. That the function of these organs, or of even the cells, does not depend on the color of the contained granules, may be inferred from the fact that in the spinal cord of the frog the cells contain colorless, instead of colored, granules.

The fact that the pigment-granules in the epidermic cells of the areolæ around the mammilla of the human female are increased in pregnancy, is well known, and its darker color is regarded as one of the signs of that condition. We can only associate this fact with the development of the whole mammary gland at the same time, in consequence of the sympathy existing between it and the uterus. It may also be added that an increased tendency to develop pigment-granules is often manifested in other parts of the body during the last weeks of pregnancy, in the form of freckles, especially of the face, neck, and upper part of the chest.

Regeneration of Pigment-cells.

In the case of a young man who had a congenital black spot on the skin just below the angle of the mouth, a blister was applied to remove the epidermis, and then the nitrate of silver till the corium was completely abraded. Still, the pigment-cells were reproduced as abundantly as before. In case of ephelis hepatica affecting the forehead, cheek, or back of the neck, the same experiment has been followed by the same result. After such failure, however, the pigment has sometimes spontaneously disappeared. In negroes, if a portion of the skin be lost, that which replaces it, for a long time, is deficient in pigment-cells. In some cases, however, the new skin, after many years, becomes as black as the original integument.

Pathological Formation of Pigment-cells.

The abnormal development of pigment-cells or granules in the tissues constitutes melanosis. The latter is not, therefore, itself ma-

lignant, but it often forms a part of cancerous and other malignant growths. Pigment-cells developed on patches of skin (most frequently of the forehead or other part of the face) constitute the disease called ephelis hepatica; it being usually associated with disease, often merely functional, of the liver. A different form of deposit of pigment on the skin is also mentioned by Queckett, in which it could be brushed off from the surface with a camel's-hair pencil. It is believed that the face only is liable to this form of deposit; and its actual existence is to be distinguished from some other pigment purposely applied by the patient (usually a female) to deceive the medical attendant.

Moles and freckles, when congenital, are due to a deposit of pigment-cells, from a cause not understood.

The deposit of pigment sometimes occurring in cases of acne has already been mentioned.

II. Cancer-cells.

Cancerous masses consist of the four following elements, in addition to bloodvessels:—

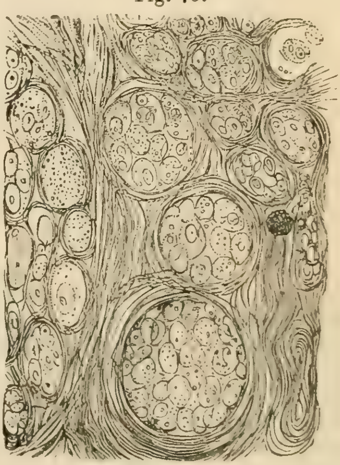
1. A matrix of homogeneous substance, either hyaline or granular.
2. Fibres more or less approaching those of white fibrous tissue in appearance.
3. A great variety of cells and nuclei, some of which are generally regarded as peculiar to cancer.
4. A peculiar cream-like fluid, termed the "cancer-juice."

These elements vary extremely in their proportion in the different forms of cancer, of which three are usually designated:—

1. Scirrhus, or *fibrous* cancer, in which the homogeneous matrix and the fibres, one or both, predominate. (Fig. 75.)
2. Encephaloid, or *cellular* cancer, being constituted mainly of cells. (Fig. 76.)
3. Colloid cancer, in which there is a predominance of a peculiar gelatinous fluid.

These three forms are often found coexisting in the same cancerous mass. Melanotic cancer is distinguished merely from having pigment-cells added to the cancer elements. (Fig. 77.)

Fig. 75.

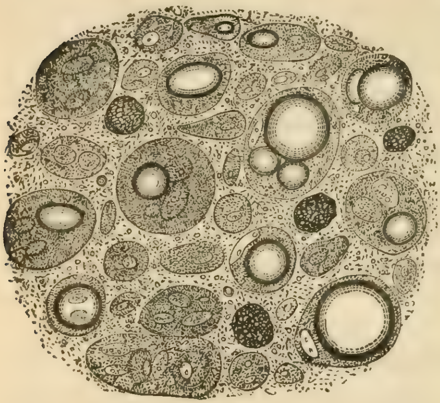


Cancer-cells in a fibrous stroma.

Neither the homogeneous matrix

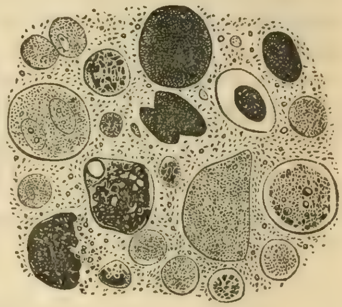
nor the fibres can be regarded as peculiar to cancer. Only the cells and the cancer-fluid are so. But, in encephaloid cancer, the fluid is

Fig. 76.



Encephaloid. Simple and compound cancer-cells.

Fig. 77.



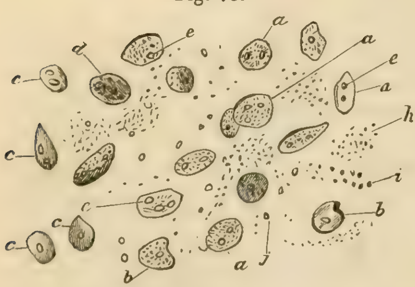
Melanotic cancer. (*Bennett.*)

not always found. The cells alone will be here described; and the investigations of Dr. F. Donaldson, of Baltimore, will be quoted, as the most explicit account hitherto given of their various forms.[1]

With a power of 555 diameters, Dr. D. found that the cells, the nuclei, and the nucleoli existing in cancer are all peculiar to it.

A. The cancer-*nuclei* (Fig. 78), whether inclosed in a cell or free, are, in their form and appearance, the most constant and unvarying of all the cancer elements. They are generally round or ovoid in shape, with a length of from $\frac{1}{2500}$ to $\frac{1}{1650}$ of an inch. Their contour is dark and well defined, the interior containing minute granules. In width they measure from $\frac{1}{3325}$ to $\frac{1}{2500}$ of an inch. It is noticeable that while in other cells the nucleus is generally found near the centre, in cancer no rule in this respect is observed. Two or more nuclei, with their nucleoli, both of great size in proportion to the diameter of

Fig. 78.



Cancer nuclei. *a.* Type form. *b.* The same, with a piece nicked out of the side accidentally. *c.* Shows a free nucleus in which the molecular granules are very minute, often met with in perfectly fresh specimens. *d.* A nucleus in which larger granules have commenced to form. *e.* The characteristic nucleolus, with its dark contour and bright centre. *h.* Fine molecular granules. *i.* The second variety of granules, or gray granulations. *j.* Fat-granules.

[1] American Journal of the Medical Sciences, vol. xxv. p. 43.

the cell, are often seen in all the varieties of cancer-cells; while other cells, as the epithelial, rarely have more than one.

B. The *nucleoli* are of a yellowish tinge and peculiar brightness, and average $\frac{1}{12500}$ of an inch in diameter. Sometimes two or three are found in the same cell. For the perfect exhibition of these characteristics of cancer-nucleoli, it is necessary that the specimen be fresh.

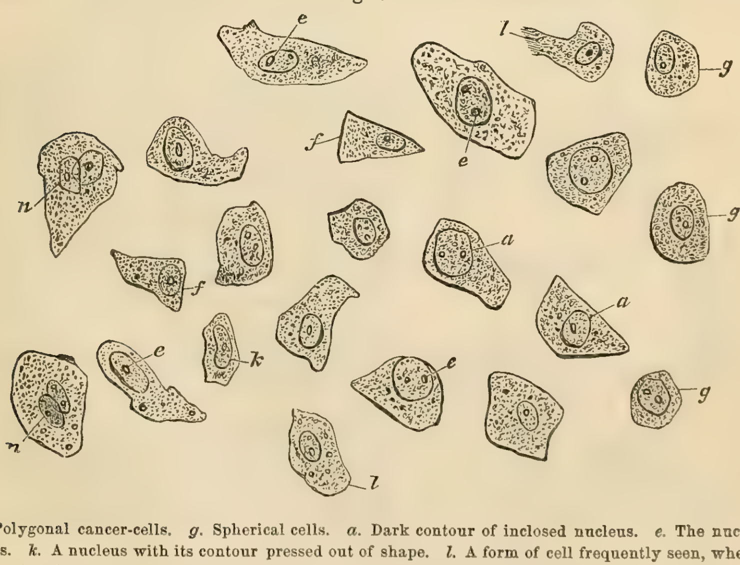
M. Robin notices the action of acetic acid upon cancer-nuclei and their nucleoli as peculiar, since it renders the nucleus and cell gradually paler, though destroying neither, while the nucleolus is entirely unaffected by it (p. 116).

C. *Cells.*—Cancer-cells present a considerable diversity of form. Dr. Donaldson mentions the following varieties:—

1. The polygonal or more or less spherical and ovoid cell.
2. The caudated cell.
3. The fusiform cell.
4. The concentric cell.
5. The compound or mother cell.
6. Agglomerated nuclei connected by granular homogeneous substance.

1. The *polygonal cell* (Fig. 79) may be regarded as the type in cancer. Thus, in hard tumors the cells are found irregular, and sometimes almost triangular in form. In medullary (encephaloid) cancer, cells of an ovoid or spherical shape are oftenest met with.

Fig. 79.

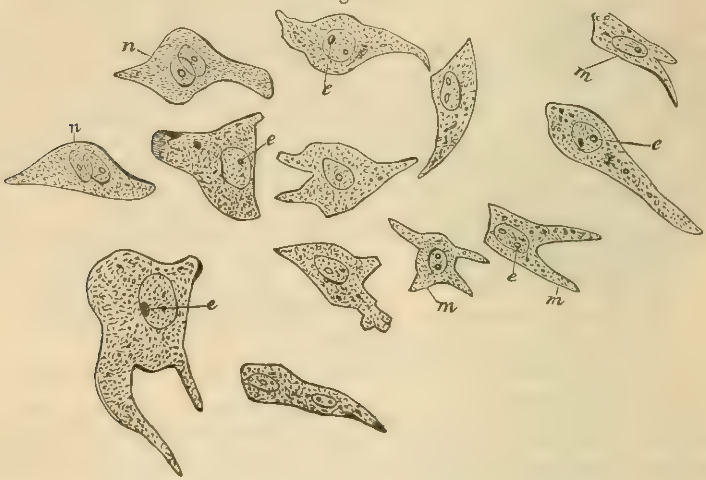


Polygonal cancer-cells. *g.* Spherical cells. *a.* Dark contour of inclosed nucleus. *e.* The nucleolus. *k.* A nucleus with its contour pressed out of shape. *l.* A form of cell frequently seen, where there is a deficiency of part of the wall. *f.* From pressure rendered triangular.

Perfectly round cells are rarely seen; though cells approaching this form, of variable diameter, are often discovered.

2. *Caudated Cells.*—This form is invariably found in the bladder, and was formerly considered *the* cancer-cell. It is of irregular form,

Fig. 80.



Caudated cancer-cells. *m.* The most usual forms. *n.* Cells containing double nuclei. Cancer of the bladder invariably contains this variety.

having from two to five prolongations or poles branching off from the body of the cell. (Fig. 80.)

3. *Fusiform Cancer-cell* (Fig. 81). —This shape is caused by a swelling in the centre, the ends being pointed so as to form an acute angle. M. Robin has *invariably* found it whenever cancer has attacked the bones. These cells somewhat resemble the fusiform fibres of fibro-plastic tissue[1] (Fig. 82), but may be distinguished from them by their greater width and length, the presence of the clear, bright centre, and the greater size of the nuclei.

Fig. 81.

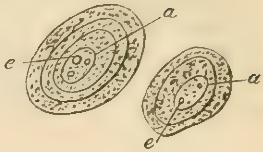
Fusiform cancer-cells. *a.* The nucleus, which in this variety of cell is almost constantly ovoid. The transverse diameter of the cell, and the size of the nucleus in proportion to the cell, together with the characteristic nucleolus, distinguish this variety from the fusiform fibro-plastic element.

[1] And have been mistaken for them by some observers.

Fig. 82.

Fusiform fibres of fibro-plastic tissue. 4. The narrow and long fusiform cell, containing a nucleus (5) with a small dot in its centre for a nucleolus. Average length of cell, 1-300th of an inch.

Fig. 83.

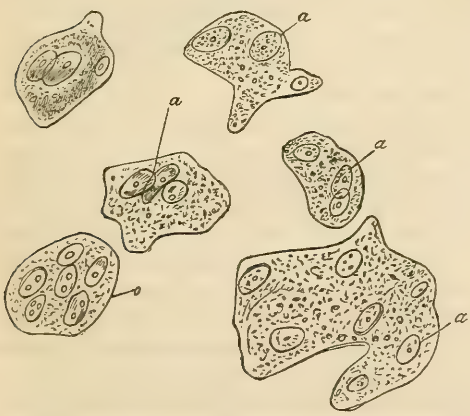


Two concentric cancer-cells. *a.* The cancer-nucleus, the size of which is always in proportion to the innermost circle. *e.* The brilliant nucleolus.

4. The *concentric cancer-cell* is formed of an ovoid or spherical body, surrounded by concentric rings, increasing in size as they go further out. This variety never forms the basis of a cancerous tumor, and is met with but rarely. (Fig. 83.)

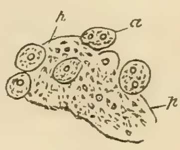
5. The *compound* or *mother cells* of cancer have received this name from the idea entertained by some authors, of their splitting up into smaller segments, and multiplying by division. They are of variable form, and often contain three, four, or more cancer-nuclei. (Figs. 84 and 64.)

Fig. 84.



Compound cancer-cells. *a.* Nucleus: when there are more than one nucleus within a cell, they are smaller than the single nucleus. *o.* From Lebert.

Fig. 85.



Agglomerated cancer-nuclei. *a* Nucleus. *p.* Granular homogeneous matrix.

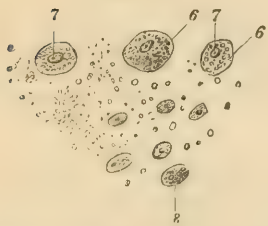
6. *Agglomerated nuclei* are also rarely met with, which seem to be held together by the granular homogeneous substance in which they are generated. They seem to have no cell-wall about them, and may be recognized by the bulk of their envelop. (Fig. 85.)

Elements liable to be mistaken for Cancer-cells.

It is important, in this connection, to specify the histological elements which may be mistaken by the microscopist for the cancer-cells just described; though, with the exception of the first two, the distinction is easily made at a glance.

1. The *fusiform corpuscles of fibro-plastic tissue*[1] are often as much as $\frac{1}{450}$ to $\frac{1}{775}$ of an inch long. Their comparative narrowness, the smallness of their nuclei, the nucleolus, and, indeed, their whole aspect, distinguish them from cancer-cells. They have already been shown by Fig. 82.

Fig. 86.



Spherical fibro-plastic cells. 6. Well-marked cell. 7 and 8. Nuclei inclosed in cells or floating free; transverse diameter, 1-5000th inch.

2. The *fibro-plastic cells and their free nuclei* (Fig. 86) may be mistaken for cancer-cells by a superficial observer. These cells are ovoid, sometimes polygonal, and vary from $\frac{1}{5000}$ to $\frac{1}{1650}$ of an inch in diameter. The nucleus and nucleolus, however, appear different from those of cancer, and the granules they contain are very much finer and of more uniform size. The *free nuclei* are so much smaller as to be at once recognized.

Both of the fibro-plastic elements just mentioned are found in the brain, bladder, ovaries, mammary gland, uterus, &c., and in the healthy state as well as in inflammatory products. These will also be found *with* cancer-cells, if inflammation has existed in a cancerous deposit.

Fig. 87.

Tubercle-corpuscles (nuclei) distinguished from cancer. 1. Corpuscles found in softened tubercular matter; small, irregularly formed, globular bodies with many nucleoli. 2. Nucleoli and interior granules. 3. Free, loose granules.

3. Mr. Bennett thinks that the cells escaping from the cavities of *enchondromatous tumors*, while they are softening, may be mistaken for cancer-cells. Dr. Donaldson does not accept this as probable.

4. Nor can pus-corpuscles be mistaken for cancer-cells, though often found mixed with the latter.

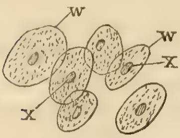
5. The appearance of *tubercle-corpuscles*, as contrasted with cancer-cells, is shown in Fig. 87. The former were, however, magnified 833 times, the cancer-cells but 555 times.

6. The contrast between *epithelial cells* in different stages of de-

[1] This is a phrase applied to the fibres, cells, &c., developed in exuded plasma, generally in case of inflammation.

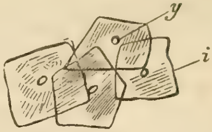
velopment, and of the various kinds, and cancer-cells, is seen in the four next figures (Figs. 88 to 91).

Fig. 88.



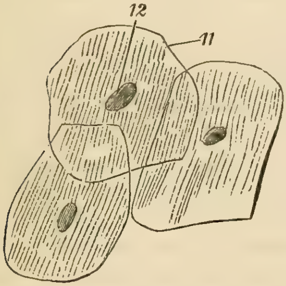
Young epithelial cells filled with few and small granules. *w*. Cell-wall. *x*. The nucleus, very small in proportion to cell, and containing no nucleolus. (*Lebert.*)

Fig. 89.



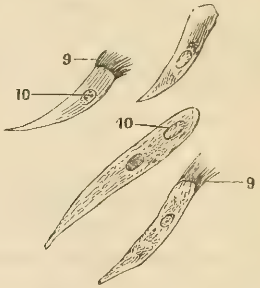
Cells from the epidermis. *y*. Nucleus without nucleolus, diminutive in proportion to cell. *i*. The cell, with homogeneous minute granulations filling up the centre. Diameter of the cell, when taken from the skin, 1-250th inch.

Fig. 90.



Buccal epithelial scales. 11. Irregularly polygonal contour. 12. The characteristic nucleus without any appearance of a nucleolus; which is rarely met with in epidermic cells, or in those coming from the buccal surface.

Fig. 91.



Ciliated epithelium from air-passages. 9. Hair-like appendages (cilia), which, during life, are constantly in motion. 10. Nucleus clear in the centre.

Since crystals of cholesterine, of ammonio-magnesian phosphate, and of margarine, fat-globules, filaments, and pus, may be found mixed with cancer-cells, Dr. Donaldson insists upon the examination of every part of a mass supposed to be cancerous, before deciding that it is not so. "If but one cancer-cell be found, it is conclusive," says Dr. Donaldson; a proposition, however, which should not be practically adopted, as will appear.

"Out of the body, cancer elements change more rapidly than any others; nor can they be preserved in any fluid;" therefore they should be examined at once. Within the first day they may become degenerated by the appearance of fatty granules, which often hide their distinctive characteristics.

Epithelial cancer will be spoken of in connection with "Epithelium."

Much discussion has arisen, of late, in regard to the value of the microscope in the diagnosis of cancer; one party contending that this instrument is totally unreliable in this respect, while the oppo-

site would rely upon it alone. The following is believed to be the only tenable view of this subject:—

1. In all cases of *well-developed* cancerous formation, the microscope, in the hands of one *skilled in its use*, will alone demonstrate the true character of the growth, unaided by any knowledge of its appearance to the naked eye, of its tactile properties, or of the history of the case. This it will do by detecting one or more of the peculiar forms of cell or nucleus already described. Here, therefore, the diagnosis may be positively expressed in the affirmative.

2. But there are all possible grades of development, from the encephaloid, as the most strongly pronounced form of cancer, to the fibrous cancer, and onward to the simple, innocent sarcoma. There will, therefore, be a corresponding shading-off of the peculiarities of the minute cancer elements (cells, nuclei, &c.) into the normal elements of the tissues. Besides, when cancer-cells are still young, they do not present the peculiarities before mentioned.[1]

In the imperfect or early development of cancer, therefore, the cancer-cell may so nearly resemble the fibro-plastic or some other cell, that a microscopic discrimination is impossible. Here, then, the microscopic diagnosis must be guarded, and the history of the case and the other sensible properties of the growth must decide.

3. The cancer elements may exist in small amount in a mass supposed to be cancerous, and in the midst of a variety of other minute elements, and therefore escape detection. If so, the microscopic diagnosis is *inferentially* negative, but not unqualifiedly so. The unaided eye, the sense of touch, and the history of the case may, however, together, decide the diagnosis unqualifiedly, either in the affirmative or the negative.

4. In cases of well-developed cancer, therefore, the microscope, since it alone may decide the diagnosis, is in the highest degree reliable. In the other two cases mentioned, it is less reliable than the other means alluded to; but here, also, it may prove of the highest value, by confirming or opposing the diagnosis suggested by them. It is the absurd assumption that the microscope can decide in every possible case, which has brought the instrument into disrepute. It merely enables us to see what would be invisible without it; and gives, so far as the minute elements are concerned, an advantage over those who refuse to use it, like that which one who has perfect sight enjoys in respect to things visible to the naked eye, as compared with the purblind. But as the unaided sight alone is almost never expected to decide, in case of suspected cancer, without regard to the tactile properties and the history of the case; so the sight, when aided by the microscope—for it is mere sight still—must not, except in a single class of cases, be relied upon alone. In these it should be recognized as an *arbiter* in the diagnosis of cancer; in all other cases it is merely a valuable aid.

[1] All *pathological newly-formed cells* have no especial character peculiar to them. (*Wedl*, p. 66.)

SECOND DIVISION.

THE FLUIDS OF THE HUMAN BODY (HYGROLOGY[1]).

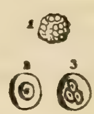
In their histological relations, the fluids may be considered under the four following chapters:—

I. The blood, including lymph and chyle.
II. Serous secretions and transudations (effusions), and exudations.
III. Mucous and glandular secretions.
IV. The cutaneous secretions.

There is, however, one histological element which is common to no less than six of the fluids about to be considered, and this will be described before entering upon the fluids individually. This element is the "cytoid corpuscle"[2] (*Henle*), and which has been variously termed the lymph-corpuscle, the chyle-corpuscle, the colorless blood-corpuscle, the mucus, the pus, and the exudation-corpuscle, accordingly as it has been found in these six fluids respectively.

Cytoid corpuscles (Fig. 92) have a granular investing membrane or cell-wall, and contain either a single round and occasionally oval or reniform nucleus, or several nuclei heaped one upon another. They are not perfectly spherical. Their diameter varies with the specific gravity of the fluid containing them, since they are highly endosmotic. Hence they are larger in saliva than in pus. The addition of water to any fluid containing them, causes them to enlarge, and their investing membrane to appear less folded and smoother. Their diameter varies, therefore, even in the same fluid,

Fig. 92.



Cytoid corpuscles of blood. 1. Natural appearance. 2 and 3. Changed by dilute acetic acid.

[1] From ὑγρὸς, wet, fluid, and λόγος. The term Phlegmatology has also been used; but its derivation being founded on the obsolete notions of the ancients respecting *phlegm*, it should be discarded.

[2] *I. e. cell-resembling* corpuscle, from κύτος, cell, and εἶδος, resemblance.

with variations in its composition. It usually ranges between $\frac{1}{2400}$ and $\frac{1}{2900}$ of an inch in the six fluids before named. Bowman remarks that these corpuscles are usually smaller in mucus than in pus, and that they are also less distinctly granular; and Hassall asserts that they are smaller in chyle than in lymph. In the blood they are specifically lighter than the colored corpuscles, since they both contain more fat, and are also deficient in the ferruginous hæmatine.

Cytoid corpuscles are also easily acted upon by extremely dilute mineral acids, or moderately dilute solutions of organic acids (uric, lactic, &c.); all of which render the nuclear matter more perceptible. And since pus easily passes into the acid fermentation, on exposure to the air, its previously invisible nuclei are at once thus rendered apparent. Hence the "pus-corpuscle," so called, when observed, has been generally found to be more granular than the "mucus-corpuscle;" and the original simple nucleus is seen to have divided into two, three, or more vesicles, in which one or two granules may be distinguished. (Fig. 93.)

Fig. 93.

Pus-corpuscles changed by acetic acid. *s.* The irregular contour of the corpuscle freed from the granules, leaving the nuclei clear. *t.* Characteristic nucleus without any nucleolus. *u.* Free nuclei, the walls having been destroyed. *v.* Remnant of contour.

But the peculiar modifications undergone by the cytoid corpuscle, in the fluids just mentioned, will be more particularly adverted to in connection with each in detail.

Development of Cytoid Corpuscles.

The lymph, chyle, and colorless blood-corpuscles are uniformly regarded as instances of free cell-development (p. 120). It is probable that the cytoid corpuscle is always so; in pus, mucus, and exudations, as well as in the three fluids just mentioned. It appears to be a general law that cytoid corpuscles are developed in any fluid approximating nearly in composition to the blood-plasma, since such a fluid contains their nutritive elements. The latter, of course, exist in exudations; and the relations to these of pus, which will be pointed out in the following chapter, demonstrate their presence in pus also. In mucus, the cytoid corpuscles are also

probably developed in the liquor muci, the latter containing their nutritive elements; and are not secreted by the epithelial cells of the mucous membrane, as is often asserted. The idea of Gluge, that pus-corpuscles are merely free nuclei, can be adopted only by such as still maintain that there is a wide distinction between them and the mucus-corpuscle (p. 116).

Functions of Cytoid Corpuscles.

The colorless corpuscles of the blood are, with very valid reasons, regarded, by T. Wharton Jones, as the parent cells of the red corpuscles; and those of lymph and chyle are formed in these fluids preliminarily to entering the blood. In the lymphatics of the spleen, and in the thoracic duct, however, the cytoid corpuscles appear already to have developed red blood-corpuscles, and which enter the blood with the lymph and chyle.

In exudations, the cytoid corpuscles constitute the basis of new tissue, as is generally understood; while in mucus and pus they appear to be developed in accordance with the law announced above, but do not advance to any higher degree of organization.

CHAPTER I.

THE HISTOLOGICAL RELATIONS OF THE BLOOD, INCLUDING LYMPH AND CHYLE.

Since lymph and chyle are, in a physiological point of view, to be regarded as blood in its primary stages of development, some remarks on these fluids may appropriately precede the description of the blood itself.

I. Lymph.

Lymph, as obtained from the lymphatic vessels, is a colorless or slightly yellowish and somewhat opalescent fluid, of a saltish, insipid taste, with an alkaline reaction. It coagulates in from four to twenty minutes after being exposed to the air, forming a gelatinous, colorless coagulum.

Seen under the microscope, lymph consists of two portions: 1. The *fluid* portion, or *liquor lymphæ;* 2. Certain morphological elements.

1. The *liquor lymphæ* is similar in chemical composition to the liquor sanguinis, as might be expected; there being, however, more water, with less albumen and fibrine. The saline and extractive matters are, however, proportionably more abundant. It is, in fact, a dilute liquor sanguinis. The albumen varies from 4.34 (*Marchand*) to 60.02 (*L'Heritier*) in 1,000 parts, and the fibrine from .32 to .52. Fat constitutes .264, and water 924.36 to 969.26 parts. Of the liquor sanguinis about 903 parts in 1,000 are water. Contrary to what has been asserted, the albumen and fibrine of the lymph appear to be identical with those of the blood.

2. The histological elements of lymph are—1. Cytoid corpuscles (lymph-corpuscles); 2. Fat-drops; and 3. Nucleus-like formations.

1. The cytoid corpuscles have already been described (p. 145). They average about $\frac{1}{2600}$ of an inch ($\frac{1}{5000}$ to $\frac{1}{2250}$) in diameter in this fluid ($\frac{1}{2526}$, *Hassall*).

2. The fat-globules present nothing peculiar. (See p. 73.)

3. The nucleus-like bodies are probably the still undeveloped cytoid corpuscles.

It should also be added that in the lymph obtained from the lymphatics of the spleen, red corpuscles, identical with those of the blood, are found. They have also been found in the lymph of starving animals. The explanation of this fact has already been given (p. 147), though it has also been suggested that they are obtained from bloodvessels opened in the search for them.

Origin.—Lymph is derived mainly from the overplus of the plasma exuded from the capillaries, into the parenchyma of organs for their nutrition, or for the formation of secretions. It, moreover, contains some of the immediate principles resulting from the dis-assimilation of the tissues.

It is impossible to calculate, with any approximation to accuracy, the *quantity* of lymph in the human body. Bidder believes that about 28.6 pounds pass from the thoracic duct into the subclavian vein in twenty-four hours—6.6 pounds being true chyle, and 22 pounds being lymph. Few will object to the last estimate as not being sufficiently high.

Uses.—Lymph, though derived from the blood, is to enter it a second time. It is, therefore, to be regarded as blood in its primary

stage of formation. As it traverses the lymphatic glands, and is elaborated by them, it approximates more and more nearly to the blood itself, till it is at last mingled with the latter from the thoracic and the great right lymphatic ducts. In the lowest animals the blood itself is scarcely a higher development than mere lymph, and in none of the invertebrata do lymphatic vessels exist. In the lowest vertebrata, also, no lymphatic glands are found, but lymphatic vessels merely, and the lymph is poured directly from these into the nearest veins.

II. Chyle.

Chyle is the fluid obtained from the lacteals (lymphatics of the small intestine) and the thoracic duct; where it is, however, of course, mixed with lymph. It results from the digestion of certain elements of the food; and the experiments of Bernard would prove that it is derived from the fatty alone. It differs in appearance with the part of the chyliferous system from which it is obtained, and with the state of the animal as to having been lately fed or not. Indeed, lymph alone exists in the lacteals and thoracic duct during fasting. Chyle also varies in different species of animals.

Human chyle is generally a milky, opalescent, yellowish white or pale reddish fluid, with a saline and mawkish taste, and an alkaline reaction. It coagulates into a very soft, friable coagulum, in about ten minutes after its removal from the vessels.

Under the microscope, the chyle shows—1. The liquor chyli; 2. The morphological elements.

1. The *liquor chyli* (intercellular fluid—*Lehmann*) is very similar to the liquor sanguinis, especially if the former be taken for examination from the thoracic duct. The amount of fibrine in human chyle is not yet precisely ascertained, but it augments while the chyle is passing through the mesenteric glands. Subtracting this element from the liquor chyli, the remainder is called the chyle-serum. This resembles the blood-serum in composition, being, however, poorer in albumen, while it is richer in water, fat, extractive matters, alkalies, and salts—especially the chlorides of sodium and potassium. Whether it is, like blood-serum, free from iron, is not yet positively decided. It becomes more turbid and milky if more fat is taken in the food, but not otherwise, whether animal or vegetable food be taken. The fat, however, diminishes while the fluid is passing through the mesenteric glands; partly, doubtless, from

the fact that it is required for the development of the cytoid corpuscles.

2. The *histological elements* of the chyle are—1. Extremely minute granules; 2. Coarse granules; 3. Distinct nuclei with nucleoli; and 4. Cytoid corpuscles. It is only during digestion, however, that these elements appear in a marked degree.

1. The granules cover the field of view like a minute veil. They constitute what Mr. Gulliver termed the *molecular base* of the chyle. Müller found them to be fat-granules surrounded by a proteine-like (albuminous?) substance. Probably no *true fat-globules* normally exist in the chyle. To this molecular base of the chyle its turbidity and milky appearance are due. It is more abundant in proportion as the food contains more fat.

2. The *coarse granules* are grouped together, and appear to be held in contact by a hyaline substance. (*Müller.*)

3. The nuclei are sharply defined, contain nucleoli, and are sometimes covered with individual granules. (*Kölliker.*)

4. The cytoid corpuscles are identical with those of lymph (p. 148). It is, however, an interesting fact, that, while they are often $\frac{1}{2400}$ of an inch in diameter in the lacteals, they are seldom more than $\frac{1}{4200}$ to $\frac{1}{3000}$ in the thoracic duct.

Colored blood-corpuscles are also always found in the chyle from the thoracic duct, these being either developed there from the cytoid corpuscles, or being derived from the lymphatics of the spleen, as already explained (p. 147).

The *quantity* of the chyle entering the blood in twenty-four hours is not satisfactorily settled. Vierordt estimates it at $5\frac{1}{2}$ pounds; Bidder at 6.6 pounds, as already stated (p. 148).

Origin.—Bernard concludes that chyle is formed by the digestion of the fat alone in the food. If this be true, chyle is scarcely otherwise than mere lymph, with an addition of fat. It is, however, very certain that not *all* the fat in the food is converted into chyle and absorbed by the lacteals, since the blood of the vena portæ is almost twice as rich in fat during the process of digestion as during fasting. And, on the other hand, it is probable that the other elements of food, besides fat, are not entirely excluded from absorption by the lacteals, since the albuminous matters of the chyle are more likely to have been admitted with the fat than to have been developed from the latter by the addition of nitrogen from the blood in the mesenteric glands, as has been suggested. Since, however, the

albumen and fibrine of the chyle may have existed in the lymph, or have been absorbed directly from the bloodvessels, it is not yet necessary to controvert the conclusion of Bernard, that the fat alone of the food is directly absorbed by the lacteals to form the chyle.

The *uses* of the chyle need not be enlarged upon after the preceding remarks upon lymph. Its abundance of fat, however, renders it more prolific than the latter in the development of the cytoid corpuscles, which are to constitute an important element of the blood; and its other elements also are developed in it, as preparatory to their admission into the latter fluid.

III. The Blood.

The histological relations of the blood are all-important, since the elements for the development of the tissues, and for the formation of the fluids, except chyle, are derived from it.

Blood is distinguished from all other animal fluids by its bright cherry-red color, which, however, undergoes certain variations in circumstances anon to be specified. It is a thick, slightly translucent fluid, with an alkaline reaction. Its specific gravity is from 1045 to 1075—averaging 1055; being less in women than in men, in children than in adults, and in pregnant women than in those not so.

Normal blood solidifies or *coagulates* after its withdrawal from the vessels, a change depending on its fibrine, and whose properties have been specified on page 90. This process includes three periods: 1. The blood becomes viscid and gelatinous in from two to four minutes after its withdrawal. 2. After seven to fourteen minutes it has become a consistent jelly. 3. The fibrine contracts and pours out from its fibrillated network a thin, colorless, or pale yellow fluid, the *serum*, which rises to the surface. This increases in quantity in proportion as the other part, the clot, contracts, its contraction continuing for a time varying from twelve to forty hours. The particulars respecting the fibrillation of the fibrine in the clot have been stated on page 92, and the microscopical appearances have been represented by Fig. 43. The clot consists of the fibrine of the blood, together with the blood-corpuscles, both red and colorless; and its lower part is of a darker, and the upper part of a brighter red than the original blood. Arterial blood coagulates more rapidly than venous; and the blood of women more rapidly and less firmly than that of men.

Seen under the microscope, while circulating, the blood consists (1) of a fluid portion—the *liquor sanguinis*—containing (2) *histological elements* of two kinds, viz., the white and the red corpuscles. Of 1,000 parts of blood, 510 to 520 are corpuscles, and from 490 to 480 are liquor sanguinis.

1. *The Liquor Sanguinis.*

The fluid portion of the blood, called the liquor sanguinis, blood-plasma, and the intercellular fluid (*Lehmann*), consists of the serum already mentioned and the fibrine. Its specific gravity varies but little from 1028. It contains all the elements necessary for the development of the tissues, viz., those of the first class, fat, and the albuminous compounds of the third class. It also contains many of the principles of the second class resulting from the metamorphosis or dis-assimilation of the tissues, as urea, creatine, &c. It may, indeed, be regarded as a solution, in 903 parts of water, of 97 parts of the principles just mentioned; for, though not all of the latter are directly soluble in water, it has been shown that all are actually in solution in the blood (pp. 55 and 48).

The following is an analysis of 1,000 parts of liquor sanguinis, by Lehmann, the specific gravity being 1028:—

Water	902.90	
Solid constituents	97.10	
Fibrine		4.05
Albumen		78.84 to 98.
Fat		1.72
Extractive matters		3.94

Mineral Substances (8.55).

Chlorine	3.644	8.55
Sulphuric acid	0.115	
Phosphoric acid	0.191	
Potassium	0.323	
Sodium	3.341	
Oxygen	0.403	
Phosphate of lime	0.311	
Phosphate of magnesia	0.222	

The *fibrine* constitutes 4.05 in 1,000 of the plasma alone, and from 2 to 2.2 (about 3—*Lehmann*) in 1,000 of the whole blood. Arterial

contains more than venous blood. There is but little in the portal vein, less in the splenic, and a mere trace or none at all in the hepatic. We shall recur (p. 158) to its uses in the blood, and its relations to the tissues, after speaking of the other elements in the plasma.

The *serum* is best obtained, in its isolated state, from coagulated blood, after the contraction of the clot has ceased. It is sometimes seen to contain a quantity of undissolved particles in suspension, which give it a milky appearance, and which consist of fat-globules, granules of precipitated albumen, or of colorless (cytoid) blood-corpuscles.

The amount of *water* in the serum is generally directly proportioned to that in the whole blood, and inversely to the number of the blood-corpuscles. A very watery serum, however, necessitates an increase of water in the individual blood-corpuscles, from endosmosis. In the serum of the blood of adult males it averages 90.5 per cent.; in that of females, especially during pregnancy, somewhat more. Arterial blood contains more water than that of the veins; that of the portal vein, however, contains the most water of all of the latter, especially during digestion, and the blood of the hepatic vein less than that of any other vessel. The serum becomes more watery in most diseases, except in the first stages of typhus fever, measles, scarlet fever, and cholera. The blood of the amphibia contains more water, and that of birds less, than the blood of the mammalia.

The principal constituent of the blood-serum is *albumen*, of which there is from 7.9 to 9.8 per cent.; and from 63 to 70 parts[1] in 1,000 of blood. (*Becquerel and Rodier.*) Arterial blood contains less albumen than venous; in the horse, as 9.2 to 11.4. (*Lehmann.*) The blood of the hepatic vein is very rich in it, while the portal vein has still less than the arteries. The quantity of albumen in the blood of the veins increases considerably during digestion. Human blood contains, on an average, more albumen than that of most mammalia. In most diseases the amount of albumen is diminished, it having been found increased only in plethora, intermittent fever, and cholera.

It is not yet satisfactorily demonstrated that *caseine* exists in the

[1] This includes about 4 parts of albuminose. (*Robin and Verdeil.*) Lehmann's analysis would, however, give only about 44 in 1,000 parts of blood, which is probably nearer the fact.

blood-serum even of pregnant women, and of the placental vessels. The "serum-caseine" may be merely albumen deficient in alkali and salts. (*Lehmann.*)

The *fats* of the serum consist principally of stearic, oleic, and margaric acids, and cholesterine. What has been called "seroline" is a mixture of the crystallizable part of these fats; these preponderating in the serum, while the more oily and yellow-colored are found in the red corpuscles. Phosphoretted substances soluble in ether do not exist in the serum, though they do in the corpuscles. The amount of fat in the serum is not precisely determined, but it is constantly increased during digestion. It is, on the average, more abundant in the serum of women than in that of men. The blood of the veins contains more fat than that of the arteries, and the portal vein the most of all (p. 77). In diseases, the ordinary fats appear to diminish, while the cholesterine increases.

Glucose, or grape sugar (p. 70), is also a constituent of the blood-serum, though in extremely small quantity. After the use of amylaceous or saccharine food it may be increased to 0.5 per cent. The blood of the hepatic vein abounds in sugar, while that of the portal vein contains only traces of it. Bernard has found that the glucose is formed in the substance of the liver, and, sometimes at least, from a nitrogenized material. M. Figuier's statement, that the sugar is formed in the portal vein and *stored up* in the liver, has not yet been confirmed.

Urea, *hippuric acid*, *creatine*, and *creatinine* exist in serum, but in quantity too small to be determined. A peculiar *yellow* coloring matter has also been supposed to exist in it, but this is not decided.

Formic, acetic, and lactic acids may also exist in the serum, since the first is formed in the perspiration, and the last in the muscles; but they have been detected only in the blood of the splenic vein. Hypoxanthine has been found in the blood of the spleen. It occurs also in case of leucæmia; as do the three acids just mentioned, and glutin.

Biliary coloring matter and *acids* occur only in diseased blood, and sometimes when there is no decided lesion of the liver. *Uric* acid has been found, with certainty, only in diseased blood, especially in arthritis.

Of the *mineral constituents* of the serum, the chloride of sodium is the most abundant, averaging 61 per cent. of the ash. Next is carbonate of soda, 28.9 per cent. Chloride of potassium varies

much, but averages about 4 per cent. of the ash; the phosphate of soda about 3 per cent.; while the sulphate of potassa depends mostly on the manner of incineration. The salts together average about .85 per cent. of the serum. They are more abundant in the blood of men and of adults than in that of women and children. There are more salts in arterial than in venous blood, except that of the portal blood, which contains more than that of the arteries. In case of repeated bleedings, more salts are found in the blood last drawn than in the first. The serum salts are much diminished in violent inflammations, and still more so in cholera; while they are considerably increased in acute exanthemata, typhus, dysentery, Bright's disease, and especially in dropsy.

The *carbonate of ammonia* is found in the blood only in severe diseases, and especially in uræmia; and almost always in the blood of cholera patients.

Origin.—The liquor sanguinis is derived from the lymph and the chyle, principally from the latter.

The sources from which its mineral constituents are originally derived have been specified in connection with each of the immediate principles, in the first part of this work. The fats are almost entirely taken in the food. The albumen is derived directly from albuminose; the latter being formed in the small intestine, as has been shown (p. 87), from the digestion of the albuminous substances (albumen, caseine, and fibrine) and the peculiar organized immediate principles (osteine, musculine, elasticine, &c.) of the food. The fibrine is also formed at once from the albuminose, or from the albumen in the blood.

Uses.—From the liquor sanguinis all the tissues and the fluids, except chyle, are formed, unless the blood-corpuscles also have some part in the development of the former; which will be shown to be improbable when the functions of the corpuscles are discussed.

Nor is it difficult to decide what is the precise function of each of the elements of the liquor sanguinis, excepting the albumen and the fibrine. The *water* is indispensable, both as a solvent of, and as a vehicle for carrying, the blood constituents to the capillaries; and it also enters into the composition of all the solids and fluids of the body (p. 45). The salts are essential constituents of the tissues and the fluids, and the use of each is specified in the first part of this work. *E. g.* common salt aids in the assimilation and the dis-assimilation of the tissues, and prevents the solution of the

blood-corpuscles in the serum (p. 50). The phosphate of lime is indispensable for the formation of bone. The *fats* are also required for the development of adipose tissue, and the formation of all the fluids containing fat (p. 77); while the other principles of the second class, as urea, creatine, creatinine, &c., result from the disassimilation of the tissues, and are to be eliminated from the blood, in the excretions, as effete materials.

In regard to the uses of albumen and fibrine, it is generally asserted by authors that the former exists in the blood principally as the material from which the fibrine is formed, though it also becomes solidified in certain organs (especially the nervous centres), and forms a part of the serous secretions and the transudations; while the *fibrine* is the only *plastic* or organizable element in the liquor sanguinis, and, therefore, the one from which all the tissues are formed.

But in the first place, it is impossible that any single immediate principle can be the source of all the tissues, since all of the latter consist of several of these principles combined. The phosphate and carbonate of lime are as indispensable in the formation of bone as is the organic substance which unites with them, whether it be formed from fibrine or albumen. Hence, also, both albumen and fibrine naturally have these salts and some others always associated with them (pp. 84 and 90). So far as this point is concerned, therefore, albumen *may* be a plastic element as well as fibrine; and it occurs at once as improbable that all the tissues can be developed and nourished from an element constituting only about $\frac{1}{333}$ part (*Lehmann*) of the blood, while another similar immediate principle exists in at least twenty times ("nearly twenty times"—*Lehmann*) that amount. But we proceed to examine the grounds of the view usually entertained.

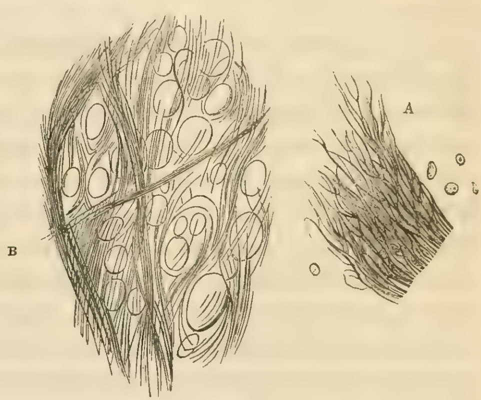
1. The tissues are said to be developed and nourished from fibrine only, because all plastic exudations contain fibrine. If this were true, we might also remember that they also contain albumen. But Lehmann asserts that plastic exudations are sometimes entirely deficient in fibrine.[1] Fibrine, therefore, cannot be the *only* organizable element in the liquor sanguinis, at any rate; *albumen* must be organizable in exudations containing no fibrine. And if so in such cases, it is probably in all, for we find no exudations not

[1] Physiological Chemistry, vol. ii. p. 290.

containing albumen. Gluge's assertion, that "the organization of fibrine into *fibres* and *cells* is a matter of direct observation," has already been quoted (p. 119). We know that it is developed into fibres by mere coagulation, but have shown that there is no proof of cells being developed from fibrine. On the other hand, they are probably never developed from fibrine, but from albumen rather; fibrine never rising to a higher organization than mere simple fibre.

2. It is asserted that false membranes are at first formed from organized fibrine alone, and that this is subsequently converted into a higher tissue, usually some modification of the areolar. It is true that the future new membrane is at first shadowed forth by the fibrillated fibrine. The latter is, however, either ultimately reabsorbed and replaced by other permanent tissues; or the fibres themselves remain, and present the appearance represented by Fig. 94. The fibrillated fibrine constitutes the matrix or nidus in which the cells and other histological elements (if any) are developed from the albumen and other immediate principles, as there is every reason to believe; and, having performed this *temporary* function, the fibrine usually disappears. If, however, no other histological elements are formed in it, it sometimes remains. The fact is undoubted that it is the *fibrine* which is organized into the *fibres*, and this alone shows that it cannot be also organized into higher elements and tissues; for every histological element has its own identity and independent vitality. Hence fibres are never converted into cells, nor any one tissue into another (p. 82). It must, therefore, be something else that is converted into cells and tissues, and we can assign no other element than the *albumen*. In respect to the tissues, therefore, *albumen*, and not fibrine, *is the plastic element* of the blood-plasma. Ordinarily, however, the coagulated fibrine

Fig. 94.



A. Fibres in fibro-cystic tumor. B. After addition of acetic acid.

must *shadow forth* the future tissue as its matrix, and hence it is almost always present in the plastic exudations.

The *histological* relations of the fibrine in the liquor sanguinis are, therefore, it is believed, comprised in the following paragraphs (pp. 91 and 95):—

1. Fibrine is the *primum organizatum* of the liquor sanguinis, the element first organized in the plasma. It therefore becomes the matrix or nidus in which other and more permanent tissues are developed. This is also the fact, whether the original development of the tissues, or the formation of pathological new growths, or the normal reparative process, be in question. Hence the blood of pregnant women contains an increase of fibrine (to 4.4 parts in 1,000) during the last two or three months of pregnancy, while the tissues of the fœtus (and its blood, also) are being most rapidly developed (p. 91).

2. But fibrine has also a not less important relation to the *blood itself*. The blood, as well as the tissues, has its own vitality to maintain; and without its power of coagulation, depending on its fibrine, the spontaneous arrest of hemorrhage would be impossible. Nor, indeed, could art long restrain it, were even the smallest vessel divided, without the aid of the clot invariably formed (p. 91). When we use pressure to arrest hemorrhage, or apply a ligature, it does so merely till the clot is formed and sufficiently organized to allow of the removal of the artificial appliances.

3. Fibrine is, therefore, a peculiar and indispensable element of the *blood, merely as such*; and it is surprising that so small a proportional amount ($\frac{1}{450}$ to $\frac{1}{333}$), has the power to secure the temporary solidification of all the blood effused in hemorrhages. Hence it may be said, indeed, that fibrine exists first and especially for the advantage of the blood alone; and secondly, for the benefit of the tissues. Thus, also, it appears that the vitality of the blood inheres in the fibrine; though in part only, as will appear in the sections upon the blood-corpuscles. Mr. Simon maintained that fibrine is an excrementitious matter. Difficult, however, as it may be to account for its increase in the blood in certain pathological states, we are obliged to reject at once the idea that the blood owes its vitality, in part, and its power of self-preservation, to an *effete* substance floating in it.

On the other hand, *albumen* is the great *histogenetic* element of the blood, since from it all the tissues are directly formed. Thus it is, indeed, directly the *pabulum* of the tissues. It is also, pro-

bably, the source of the fibrine in the plasma; both the latter and the tissues assimilating it to themselves (p. 86).

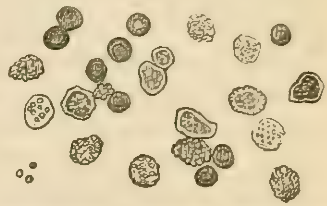
2. *The Blood-corpuscles.*

The blood of the lowest animals consists of a fluid merely, the analogue of the liquor sanguinis already described. As we ascend in the scale, we first find colorless corpuscles added to this portion; and, in the vertebrate animals, still a third element, also, the colored corpuscles.

A. *The Colorless Corpuscles of the Blood.*

The colorless corpuscles of the blood (lymph-corpuscles—Figs. 95 and 96) are the *cytoid* corpuscles already described (p. 145) as existing in lymph, chyle, and exudations. They are far less numerous than colored corpuscles (1 to 346, or even 400 in adults[1]), are more globular, though not perfectly spherical, and are not elastic. They average $\frac{1}{2400}$ of an inch in diameter. They have a granular cell-membrane, or capsule, and either a single round or reniform nucleus, or several small nuclei heaped upon each other. They are lighter than the red corpuscles, since they contain a larger amount of fat, and are also deficient in the iron contained in the latter. The capsule is so viscid, that they possess a well-marked tendency to conglomerate into larger or smaller groups. Hence, while circulating in the capillary vessels, they are seen rolling slowly along upon the internal surface, while the red corpuscles move rapidly on in the central portion of the blood-column. Their quantitative analysis has not been attempted.

Fig. 95.



Colorless blood-corpuscles. (Magnified 400 diameters.)

The *cell-membrane*, or capsule, is probably an albuminous substance.

The *contents* of the cytoid corpuscles consist of an albuminous solution, containing extremely fine granules in suspension, most of which are formed, doubtless, of fat. A distinct molecular motion is produced in them by the endosmotic action of water.

[1] Moleschott finds the proportion in children $2\frac{1}{2}$ to 12 years old, as 1 to 226; at 22 years, 1 to 330; 30 to 50 years, 1 to 346; 60 to 80 years, 1 to 381; women when menstruating, 1 to 247; not menstruating, 1 to 389; in pregnancy, 1 to 281.

The *nuclei* are single, double, triple, or multiple. They are rendered more visible by the action of water, but dilute acetic acid exposes them by dissolving the cell-wall.

The size of the colorless corpuscles is varied by the endosmotic action of the fluid portion of the blood; hence the richer the blood is in water, the larger they are, and *vice versa* (p. 145).

The cytoid corpuscles of the blood are more abundant in young animals, and after venesection; and in the blood of pregnant women during the last months of pregnancy. They are also more abundant in venous blood. (*Kölliker.*) An abnormal development of them constitutes *leucœmia.* Pyæmia, also, is scarcely distinguishable from the latter, since the pus-corpuscle is not to be distinguished from that under consideration, as will be shown under the head of "Pus."

Origin.—The colorless blood-corpuscles, like all other cytoid corpuscles (p. 146), are originally developed, by free cell-development, in the lymph, the chyle, and perhaps also the liquor sanguinis. Secondarily, however, new cells may, doubtless, be developed from pre-existing ones, and thus their multiplication seems actually to occur. Lehmann states that they are, "under certain conditions, doubtless formed in the liver; but their formation, or, at all events, their development and growth, are not confined to any one definite locality, but proceed in the vessels of very different organs." Kölliker maintains that the cytoid corpuscles of the chyle originate in the minutest lacteals. He there found nuclei, either free or surrounded by granules, and very fragile young cells, with walls almost touching the nucleus, and states that they increase in size on their way to the thoracic duct. In the latter he found none of these nuclei, but two kinds (larger and smaller) of lymph-granules; and maintains that the smaller only are converted into the red blood-corpuscles, while the larger are gradually dissolved in the blood. The various phases of their development are shown in Fig. 96.

Fig. 96.

Colorless blood-corpuscles in various phases. *a, a.* Stellate form occasionally seen after escape of their contents. *b, b.* Free nuclei. *c.* A nucleus surrounded by a few granules. *d, e.* Small cells, some with a distinct nucleus. *f, g.* Larger cells, one with a visible nucleus. *h.* Similar cell after addition of water. *i.* Similar cell after addition of acetic acid.

Uses.—Histologically, the cytoid cor-

puscles of the blood (especially the smaller) may be regarded as merely a transitional stage of development of the red corpuscles. The idea of Kölliker, however, that they are not all converted into the colored corpuscles in the human body, is confirmed by comparative histology; since in all the white-blooded animals they are arrested in their development, and form no colored corpuscles, though they are in some animals quite abundant.

The manner in which the red corpuscles are developed from those under consideration will be specified in the following section (p. 168). But it should be here added that even in the white-blooded animals they cannot, during their development and their metamorphosis, be without influence on the composition of the blood, and thus, directly or indirectly, on the development and the metamorphosis of the tissues. Besides, they will incidentally secure a patulous condition of the minute vessels, and thus subserve the circulation of the liquor sanguinis in these species. The former remark may also be applied to the human cytoid corpuscles, since they are living cells manifesting an active interchange of matter with the blood-plasma.

To them, therefore, as well as to the fibrine, the blood owes its vitality. Those who maintain that fibrine is the *pabulum* of all the tissues, have suggested that the colorless corpuscles elaborate fibrine from the albumen in the blood. This is quite improbable; for though the amount of fibrine and the number of colorless corpuscles are sometimes simultaneously increased (as in inflammation), there are no grounds for the opinion that these cells contain any fibrine at all.[1] In leucæmia, also, the cells are abnormally numerous (even one to three red blood-corpuscles), while the fibrine is not increased; and the same is also true of the blood of young and growing animals. They are, therefore, to be regarded as entirely independent, histologically, of fibrine, and their increase or diminution must be attributed to causes acting independently upon them. Wherever growth is going on, cytoid corpuscles appear—*e. g.* in new formations, reparative or otherwise, or in the original development of the tissues—and it might be expected that they would be developed rapidly in the blood also of young animals, as one of its normal constituents; its metamorphosis being rapid, as

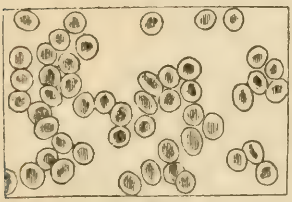
[1] An increase of fibrine in the blood is perhaps always attended by an increase of white corpuscles, but the converse of this does not hold.

well as that of the tissues. On the other hand, in leucæmia there appears to be rather a general arrest of development of the white corpuscles, and thus a great proportional diminution of the colored ones. That the cytoid corpuscles of the blood are also liable to disease, especially to fatty degeneration, is a fact recently established by the investigations of Wedl and others.

B. *The Colored Blood-corpuscles.*

The colored blood-corpuscles (red corpuscles, blood-cells, blood-disks—Fig. 97), which, in their natural or moist state, constitute 510 to 520 parts in 1,000 of blood, and about one-half of its mass, are thick, circular, slightly biconcave disks, averaging $\frac{1}{3333}$ of an inch ($\frac{1}{3000}$ to $\frac{1}{2700}$, *Hassall*) in diameter. Their thickness at the circumference is about one-fifth of their diameter. Their specific gravity is 1088.5 to 1088.9 in men, and 1086 to 1088 in women. They consist of a colorless cell-membrane, with red, or, by transmitted light, yellow viscid contents. Some of them are also originally found to contain one or more amorphous granules, but none ever contain a nucleus. The corpuscles of the embryo are somewhat larger than they are after birth. All the mammalia have circular and discoid blood-corpuscles, except the camel, the dromedary, and the lama, in which they are elliptical and biconvex. In birds the corpuscles are long and oval, elevated in the centre, and thick at the margin; in the amphibia they are oval and very convex. Those of most mammalia are smaller than those of man, while those of the amphibia are far larger—in some cases (the proteus) $\frac{1}{350}$ of an inch in diameter.

Fig. 97.



Colored blood-corpuscles. (Magnified 400 diameters.)

The following are the mean dimensions of the blood-corpuscles of several of the lower animals, compared with man (*Schmidt*):—

Man . .	$\frac{1}{3333}$	Mouse .	$\frac{1}{4188}$	Elephant .	$\frac{1}{2745}$
Dog . .	$\frac{1}{3570}$	Ox . .	$\frac{1}{4663}$	Frog	$\frac{1}{425}$ to $\frac{1}{1635}$
Rabbit .	$\frac{1}{4000}$	Cat . .	$\frac{1}{4800}$	Siren . .	$\frac{1}{435}$
Rat . .	$\frac{1}{4000}$	Horse .	$\frac{1}{4710}$	Proteus .	$\frac{1}{350}$
Pig . .	$\frac{1}{4166}$	Sheep .	$\frac{1}{5700}$		

It is evident that the blood-corpuscles and their viscid contents must have a different composition from the intercellular fluid, or

liquor sanguinis, in which they float. The following is Lehmann's analysis of 1,000 parts of corpuscles, the specific gravity being 1088.5, the water being to the solids as 2.14 to 1, and the organic to the inorganic constituents as 40 to 1.

One thousand parts of blood-corpuscles contain—

Water	688.00	
Solids	312.00	
Hæmatine		16.75
Globuline and cell-membranes		282.22
Fat		2.31
Extractive matters		2.60

Mineral substances without iron (8.12).

Chlorine	1.686	
Sulphuric acid	0.066	
Phosphoric acid	1.134	
Potassium	3.328	
Sodium	1.052	8.12
Oxygen	.667	
Phosphate of lime	.114	
Phosphate of magnesia	.073	

The cell-*membranes*, once erroneously believed to be fibrine, when isolated, form, in the moist state, a whitish-gray adhesive mass, which has not a fixed composition. (*Lehmann.*) In the hepatic veins the cell-membranes are distinguished from those of all other vessels in not being made entirely to disappear by the addition of water. They are, probably, an albuminous substance; but not fibrine, nor the deutoxide of protein, as has also been stated.

The viscid *contents* of the blood-corpuscles have been said to consist principally of the coloring matter called hæmatine, held in solution by the globuline. Lehmann, however, terms it, as a whole, *hæmato-crystalline.* We prefer the term *hæmato-globuline* (p. 96). There is from 18 to 26 per cent. of dry hæmato-globuline in the moist corpuscles; in the whole blood, from 9 to 12 per cent. But the hæmatine and globuline do not stand in a definite numerical relation to each other. The insoluble ferruginous substance called hæmatine does not exist as such in the blood, but is a product of the transformation of the actual blood-pigment (p. 103). In the blood the latter is soluble, and it is calculated to constitute 16 to 17

per cent. of the contents of the blood-corpuscles of an adult man. The iron in the ash of the corpuscles belongs to the hæmatine alone, and varies with it—constituting 6.64 per cent. of the hæmatine, and 4.348 per cent. of the dry corpuscles. (*Schmidt.*[1]) But a considerable part of the *fats* of the blood is also contained in the red corpuscles—their quantity amounting to .2 or .3 per cent. of the moist cells. It appears that more fat is found in the cells of venous than of arterial blood. The so-called extractive matters also exist in the blood-corpuscles; of which, however, neither the amount nor their precise composition is known. Of the *mineral* constituents of the blood-corpuscles, the phosphates and the combinations of potassa are in great excess over the chlorine and the sodium combinations. The common salt is confined almost entirely to the serum of the blood, as already shown. The cells of arterial blood always contain more salts than those of venous blood; but those of the hepatic vein are especially rich in them. Finally, the *gases* of the blood are especially contained in the corpuscles. These are carbonic acid gas, oxygen, and nitrogen. Whipped blood absorbs 1½ times its volume of carbonic acid gas, and only 15 per cent. of its volume of oxgen. Nitrogen is not more largely absorbed by blood than by water, and about equal quantities are found in arterial and venous blood.[2] There is only more oxygen relatively to carbonic acid in arterial than venous blood; the proportions being in the former as 6 to 16, and in the latter as 4 to 16. That these gases exist in great part in the blood, and especially in the corpuscles, in a chemical combination, though a loose one, is no longer doubtful (*Lehmann*); there being from 11 to 14 times the amount that could be taken up by mere mechanical absorption. The hæmato-globuline manifests a remarkable affinity for them. There are other gases, however, as carbonic oxide and several carbo-hydrogens, which combine with the corpuscles so energetically as to blacken or even to destroy them. It has already been stated that the gases in the blood are in a *fluid* state (pp. 43, 44).

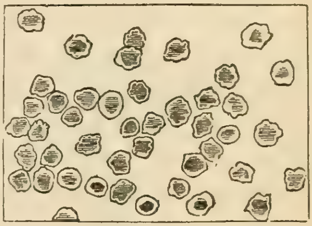
[1] The metallic iron constitutes 1 part to 230 of dry corpuscles, 1 to 229 in women, 1 to 248 in pneumonitis, 1 to 269 in chlorosis, and 1 to 249 in pregnancy; in the first stage of typhus, 1 to 220. The blood-cells in the hepatic veins contain but two-thirds as much iron as those in the vena portæ. In hydræmia the cells contain an excess of peroxide of iron; the globuline being diminished, and thus the hæmatine relatively increased. (*Schmidt.*) Berzelius found less iron than Schmidt in the dry corpuscles. (See p. 102.)

[2] Robin and Verdeil say 1½ times as much in arterial as in venous blood.

Whipped blood also contains certain morphological elements called *fibrinous flakes.* They do not, however, consist of fibrine, but are more allied, chemically, to horny substances; consisting of epithelial cells, partly from the inner coat of the vessels, and partly of fragments from the cuticle of the observer, as Brüch suggests, which have fallen into the blood. The fragments of destroyed cell-membranes have also been mistaken for them.

The cell-membrane of the blood-corpuscles being powerfully endosmotic, the latter undergo changes of form from currents between their contents and the intercellular fluid, and hence, also, changes in specific gravity. The latter, of course, *increases* when water is abstracted from them, and *vice versa.* Evaporation, or the addition to the blood of small quantities of neutral alkaline salts, sugar, or gum, may remove a part of the water; when they may present the shrivelled appearance represented by Fig. 98. Repeated bleedings also increase the specific gravity of the blood-corpuscles. (*Lehmann.*)

Fig. 98.



Blood-corpuscles shrivelled by chemical agents.

On the other hand, an increase of water in the corpuscles diminishes their specific gravity, and may distend them till they become almost spherical, or even burst. Hence their lower specific gravity in anæmia. They are also lighter when they contain an excess of fatty granules.

These changes in the weight and the form of the blood-cells affect both their tendency to sink in the plasma (and thus modify the appearance of the clot), and also modify the color of the blood.

1. The "tendency to sink" is increased by an increased specific gravity of the corpuscles; and, apparently, also by an excess of carbonic acid in the corpuscles, and a diminished quantity of albumen in the serum. At least, the blood in inflammations manifests the peculiarities of composition just mentioned; and in this state, also, the corpuscles sink more rapidly than those of healthy blood. The effect of this peculiarity on the color of the clot has been alluded to (p. 93). The aggregation of the corpuscles into nummular rolls (Fig. 99) seems to be a consequence, rather than a cause, of this

Fig. 99.

Blood-corpuscles in nummular rolls. Surfaces entirely adherent at *a*, and partially at *b*.

increased tendency to sink, since, on sinking, they necessarily apply their broad sides to each other.

2. The precise *color* of the blood, as a whole, depends very much on the shape of the blood-corpuscles, and therefore indirectly upon physical conditions, some of which have been already mentioned. While the corpuscles retain the biconcave form, their color is lighter; when distended by endosmosis so as to become biconvex, they disperse the light more, and thus render the blood, as a whole, darker. Hence all substances abstracting water from the blood-cells without decomposing them, and thus rendering their central depression more distinct, produce in it a bright red to a vermilion color—as all neutral alkaline salts, solutions of sugar, &c.; while those agents which render them more nearly spherical—as water, ether, and dilute organic acids—give to the blood a dark bluish-red color. Still, the form alone does not always determine the color; for the blood-cells of the amphibia are naturally biconvex, and cannot become biconcave, and yet they are colored bright red by the solutions of sugar and of the salts mentioned above. The following salts produce a vermilion color in the blood of the mammalia, of birds, and of the amphibia: sulphates of potash and soda, nitrates of potash and soda, chloride of potassium, phosphate of soda, carbonate and bicarbonate of soda, ferro-cyanide of potassium, borax, iodide of potassium, sulpho-cyanide of potassium, sal ammoniac, sulphate of magnesia, &c.

But the *thickness of the cell-membranes*, and their *amount of folding*, must also influence the color of the blood. If the cells are collapsed, the membrane is thicker and folded; if distended, they are thinner and smooth. In the latter case, the coloring matter shines through in its natural hue, which is a very dark red; as in a thin milk-glass a dark red fluid still appears so, but in a thick one, light red. Hence the darker color, usually, of venous blood, and the fact that all substances which corrugate the cell-membranes render the blood dark red, as acetic acid, the alkalies, &c. The above-mentioned salts, when found experimentally to give a brighter color to the blood of the amphibia, are seen to wrinkle the large blood-cells. According to some, oxygen also contracts, and carbonic acid gas expands the corpuscles; and herein is another cause of the bright color of arterial, and the darker hue of venous blood. It is also found that if even colorless solid substances strongly reflecting light are mixed among the corpuscles, they give to the mass of blood a brighter red tinge.

Hence the bright color of the fatty blood of drunkards; and the blood in leucæmia is also bright red, since the cytoid corpuscles, in which it abounds, strongly reflect the light.

Thirdly, it must be admitted that chemical combinations with the blood-pigment, especially of oxygen and carbonic acid, affect the color of the blood; the former rendering it lighter, and the latter darker colored. Indeed, all the salts which at first contract the blood-cells, and render the blood lighter colored, entirely dissolve them when in a more concentrated solution, and then give to the blood a deep dark-red hue.

The *proportional amount* of the moist corpuscles has already been generally stated at 510 to 520 in 1,000; the extremes in adults being 472 and 542, and the average 512. The blood of women, however, especially in pregnancy, contains a smaller proportion of them, which is also diminished by repeated losses of blood and other fluids. Of the lower animals, the blood of swine contains the greatest amount of corpuscles; that of the amphibia comparatively few of them.

The *enumeration* of the blood-cells has been recently attempted by Vierordt and Welcker, and it is found that from 42,700,000 to 45,500,000 corpuscles exist in a single cubic line of healthy human blood! (*Lehmann.*) Assuming the whole amount of blood to be 20 pounds, their whole number is about 65 billions and 570,000 millions. They are more numerous in venous blood. (*Kölliker.*)

In former analyses, the blood-corpuscles were previously *dried*, and were then found to constitute about 140 parts out of 1,000 of blood. The following is the analysis of Becquerel and Rodier, showing the elements in the liquor sanguinis and corpuscles, taken together; the mean being given for both men and women:—

	Man.	Woman.
Water	779.0	791.1
Solid constituents . . .	221.0	208.9
Fibrine	2.2	2.2
Corpuscles	141.1	127.2
Albumen[1]	69.4	70.5
Fat[2]	1.6	1.6
Extractive and salts of serum .	6.8	7.4

[1] This is too high an estimate for the albumen. (See note, page 153.)

[2] The amount of fat in the blood is not sensibly affected by its amount in the food.

Origin.—The blood-cells first formed in the embryo appear to have their origin in the primordial cells of the germinal structure; some of these developing tissues, and others becoming isolated and metamorphosed into blood-cells. These also are multiplied by bipartite division (p. 126). But in the human embryo the first brood of corpuscles disappears entirely by the end of the second month, when the lymph and chyle begin to be poured into the blood, and when they are superseded by those developed from the lymph and chyle-corpuscles. (*Paget.*) The first blood-cells are larger than the subsequent ones; being about $\frac{1}{2500}$ of an inch in diameter, and nucleated. The nucleus is $\frac{1}{5000}$ of an inch in diameter, central, circular, very little prominent on the surface of the cell,

Fig. 100.

Development of first set of red corpuscles (mammalian embryo). A. Dotted nucleated and nucleolated embryo-cell. B. Same with a dividing nucleus; the division being complete at C. At D, the cell also is dividing. E. Cell still containing a few granules. F. Perfect blood-corpuscle.

Fig. 101.

Phases of the red blood-corpuscle (man). *a* and *b*. Colorless corpuscles or granule-cells in the coarsely and the finely granular state. *c* and *d*. Nucleated cells without and with color. *e*. Free cellæform nucleus, or perfect red corpuscle.

and slightly granular or tuberculated. Fig. 100 shows the several stages of their development.

The doctrine that the *continued* development of the red corpuscles occurs from the colorless corpuscles of the blood, is the most plausible, though open to some objections. Mr. Wharton Jones has shown that in the whole animal kingdom five forms of blood-corpuscle are to be met with (which are represented by Fig. 101), viz: 1. Coarse granule-cells (*a*); 2. Fine granule-cells (*b*); 3. Colorless nucleated cells (*c*); 4. Colored nucleated cells (*d*); 5. Colored non-nucleated cells (*e*), or perfect red corpuscles of man and the mammalia. These

five forms are believed to correspond to as many stages of development. The third form (the colorless nucleated cell) is, however, the highest stage of development in the white blood of the invertebrate animals. The "colored nucleated cell" (fourth stage) is the highest form in the oviparous mammalia; while the "colored non-nucleated cell" is the perfect blood-cell of the mammalia. It does not, however, follow that the human blood-cell passes through the five stages mentioned by Mr. Jones, nor that any stage corresponds precisely with one of these. There is, however, a general correspondence not without interest. The following account of their development is extracted from Mr. Paget's lectures,[1] and which may be accepted as the most reliable hitherto. Fig. 102 represents the five stages of

Fig. 102.

Development of the red from the colorless corpuscles of the blood. A. Cytoid corpuscle. B. Same, being converted into a red corpuscle. C. Cytoid corpuscle with its membrane raised by the action of water. D. Same, having lost most of its granules. E. Same, acquiring color; a single granule remaining like a nucleus. F. Perfect red corpuscle.

development of the colorless into the colored cell; though the improbability has already been remarked that *all* the cytoid corpuscles are thus transformed (p. 161):—

"The white corpuscle, at first tuberculated, containing many granules, and darkly shaded (A), becomes smoother, paler, less granular, and more dimly shaded or nebulous (B). In these stages the cell-wall may be easily raised from its contents by the contact and penetration of acetic acid, or by the longer action of water (C); and, according to the stage of development, so are the various appearances which the contents of the cell thus acted on present. In the regular progress of development, it becomes at length impossible to raise the cell-wall from its contents (D). Then the corpuscles

[1] On the Life of the Blood. 1848.

acquire a pale tinge of blood color, and this always coincides with the softening of the shadows which before made them look nebulous, and with the final vanishing of all the granules, with the exception sometimes of one, which remains some time longer like a shining particle in the corpuscle, and has probably been often mistaken for a nucleus (E). The blood color now deepens, and at the same rate the corpuscles become smooth and uniform; biconcave, having previously changed the nearly spherical form for a lenticular or flattened one; smaller, apparently by condensation of their substance, for at the same time they become less amenable to the influence of water; more liable to corrugation and to collect in clusters; and heavier, so that the smallest and fullest colored corpuscles always lie deepest in the field (F). Thus the most developed state of the mammalian red corpuscles appears to be that in which they are full-colored, circular, biconcave, small, uniform, and heavy. This is the state in which they appear to live the longer and the most active part of their lives."[1]

It will be observed that Mr. Paget regards the mature blood-corpuscles not as mere free nuclei, as some observers have done (p. 115), but as non-nucleated cells. The blood-cells of the amphibia are, however, always nucleated.

The idea maintained by Weber and others, that the liver is the special agent in the development of the blood-cells in the embryo, appears to be applicable to oviparous animals, but not to the mammalia. The fact, however, that the blood of the hepatic vein in man contains a much greater amount of blood-cells than does that of the vena portæ, indicates that they are developed with peculiar activity in that organ. This, however, may be a mere consequence of the fact that the blood of this vein is also rich in colorless corpuscles, and which undergo their development while in the hepatic vessels, independently of any peculiar action of the liver itself.

Thus the life of the blood is seen to inhere in the red corpuscles, the colorless corpuscles, and the fibrine (pp. 158 and 161).

Function.—The view which ascribes to the red corpuscles the function of absorbing oxygen while in the lungs, and giving it partially off in the capillaries, while they also absorb carbonic acid in the capillaries, and give it off in the air expired from the lungs,

[1] The necessity of fatty elements in aid of the development of the blood-cells is inferred from their composition, already stated. Hence, also, their rapid formation from the use of cod-liver oil, as observed by Popp.

has been controverted by the observations of Hannover (p. 103) and Marchand; though Lehmann regards it as "completely proved." The fact that chlorotic persons exhale as much carbonic acid as those in health, may be explained by the supposition that, there being a certain amount to be removed, each corpuscle absorbs more than in health; and the fact that the liquor sanguinis always absorbs a part of this gas. It is also very certain that a part of the oxygen taken up by the blood-cells is only mechanically absorbed, while a part (and probably the greater portion) acts chemically upon their constituents. Lehmann found that after the inspiration of oxygen the mineral substances and the hæmatine in the blood-corpuscles increased, while the organic substances, and more especially the fats, were considerably diminished; the latter being destroyed by oxidation, and their effete products being transferred to the intercellular fluid, or, at all events, undergoing a considerable loss of weight by the formation of carbonic acid and water. Heat is also evolved in connection with the formation of the latter.

The blood-cells, therefore, have a direct relation to the function of respiration (aeration), and to the rapidity of the metamorphosis and repair of the tissues. Hence, in the different species of animals, we find a direct ratio between the normal amount of the blood-cells in the blood, the activity of the aerating process, the waste of the tissues and their repair (and, of course, the amount of food required), and the natural (or organic) heat of the organism. But the oxygen merely mechanically contained in the blood-cells also leaves the latter in the capillaries and combines with the tissues, thus securing their metamorphosis also, and again developing heat.

At present, therefore, we must regard the blood-cells as the great agents for effecting the dis-assimilation of the tissues, and of the blood itself. And since vital phenomena are impossible without a constant metamorphosis of the molecules of the tissues manifesting them, the blood-cells are indispensable in all the more active species of the animal kingdom, and incidentally the natural temperature of each is proportioned to their activity. Still, the corpuscles are only the *special*, but not the sole carriers of oxygen; the blood-plasma also, to some extent, possessing that power. Hence the slow dis-assimilation and low temperature of the invertebrata may be secured without them. In some of the latter, also, which possess a high degree of activity (as the insects), the corpuscles are not required, since oxygen is brought into direct contact with all their tissues

through the ramifications of the tracheæ, which open upon the surface of their bodies.

Lehmann's idea, that the blood-cells are laboratories in which the individual constituents of the plasma are prepared for the higher function of aiding in the formation and reproduction of the tissues, is scarcely tenable, since the nutrition of the tissues is equally perfect, so far as can be perceived, in animals whose blood is destitute of this histological element. Indeed, that the red corpuscles have any direct relation to the formation of the tissues, is very improbable; *dis*-assimilation and the consequent development of vital force being, it is believed, their special function.

We have no certain knowledge of the length of time the blood-cells exist. Since the cells of the same blood differ in the length of time during which they resist chemical agents, it is probable that the more easily decomposed, and which are usually of a deeper color, are the older; while the paler and less easily acted upon, and which present in their granules the rudiments of a nucleus, are of more recent origin. That their regeneration is not very rapidly effected is probable, from the fact that the blood is poor in corpuscles for several days after a moderate venesection, and exhibits a great deficiency of them for a prolonged period after repeated bleedings; and since there is a copious supply of colorless corpuscles after severe losses of blood. If, however, they *are* slowly regenerated, they cannot have a very short existence, since otherwise the number of the colored cells would not so far exceed that of the colorless corpuscles. (*Lehmann.*)

Whether the blood-cells are disintegrated in one particular part or organ, is not yet satisfactorily decided. Schult designated the liver, and Kölliker the spleen, as the organ where this process is effected. On the other hand, Gerlach and Schaffner regard the spleen as the organ in which the corpuscles are formed. Scherer's investigations confirm the idea of Kölliker. If there be a particular organ in which the corpuscles are formed, and another in which they are disintegrated and dissolved—which is still very doubtful, however—we should mention the liver as the former, and the spleen as the latter (p. 170).

Quantity of Blood in the Human Body.

Very different estimates of the whole amount of blood have been

made,[1] it being usually stated that its weight constitutes one-fifth of that of the whole body. Ed. Weber has, however, recently instituted some experiments, according to which only one-eighth of the weight of the body is blood, or 18 pounds for a man weighing 144 pounds. Lehmann calculates that the whole amount of blood in a young man is 17½ to 19 pounds. The estimate of Weber appears to be the most accurate hitherto made. It is calculated that only one-third of the whole blood can be lost rapidly without fatal consequences. But much more than this may be ultimately lost by frequently recurring hemorrhages, the vessels thus having time to adapt themselves to the diminished amount of their contents, so that the circulation is still maintained.

Varieties in the Composition of the Blood in different Physiological Conditions.

1. *Sexual varieties.* The blood of women is of a lighter red color than that of men, is specifically lighter, contains more water, and evolves a less intense odor of perspiration when treated with 1½ times its volume of sulphuric acid. It generally contains less corpuscles, but the same amount of fibrine (*Lehmann*); and some more serum in proportion to the clot. It usually contains more albumen and salts (especially the soluble), and less fat and extractive matters.

2. In *pregnancy* the blood is darker than usually, is richer in water and poorer in corpuscles and albumen, and therefore specifically lighter. There are no certain data respecting the fats and salts; but the fibrine is relatively increased in the last months, and the clot is generally very small, with a superficial stratum of fibrine frequently resting upon it (p. 158).

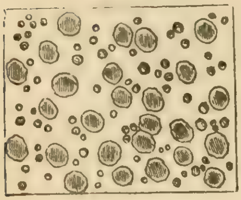
3. *Varieties depending on age.* The blood of *new-born infants* abounds in solid constituents, especially blood-corpuscles and iron, while it is poor in fibrine and salts. It contains about the same amount of fat and albumen as in the adult, and a much larger proportion of extractive matters. In *advanced life*, and in the female after the cessation of the catamenia, the blood is poorer in corpuscles, and the serum loses in some of its constituents, but the cholesterine increases.

4. During *digestion*, both the plasma and the cells become richer in solid constituents; though the latter experience a relative loss

[1] Blumenbach estimates it at 8½ to 10 pounds; Reil at even 44 pounds.

in hæmatine. The fibrine coagulates more slowly, and is richer in fat; the serum is denser, sometimes even exhibiting a milky turbidity from an abundance of fat-globules (Fig. 103) and cytoid corpuscles. The fat, albumen, extractive matters, and the salts of the serum are also pretty uniformly augmented.

Fig. 103.



Fat-globules in blood.

5. Among the *lower animals*, the blood of the omnivora (hog, &c.) is the most abundant in *corpuscles* (and therefore in soluble phosphates of iron); birds are next in order; then the carnivora and the herbivora. Of *fibrine*, the blood of birds contains the most; then that of the omnivora, herbivora, and the carnivora. Of *fat*, the blood of birds also contains most; then the carnivora and the herbivora. The blood of the mammalia contains more *albumen* than that of birds. The solid constituents of the serum also preponderate in the omnivora. In the cold-blooded vertebrata (fishes and amphibia), the blood is poorer in corpuscles and richer in water than in the warm-blooded.

Normal Differences in Composition of the Blood in different Vessels.

A. In *arterial* blood the red corpuscles are less numerous than in venous blood (*Kölliker*), and contain more water and less solid constituents; though they have relatively more hæmatine and salts, but far less fat. The white corpuscles are also less numerous. (*Kölliker.*) The intercellular fluid of the arteries is richer in fibrine than that of venous blood, and its serum contains somewhat more water and less albumen[1] and fats; while their extractive matters are slightly increased, and the salts still more so. Arterial blood also contains more oxygen, but only relatively to its carbonic acid gas (p. 164). It absolutely contains more of both these gases than venous blood, and about the same amount of nitrogen (pp. 44, 164).

B. The blood of certain veins is peculiar.

1. *The portal vein.* During digestion, if sufficient drink has been taken with the food, the portal blood is rich in intercellular fluid and in water, and the number of blood-cells is therefore small. The fibrine is slightly, and the fat considerably, increased; while the albumen, extractive matters, and salts are moderately so. Compared with the blood of the jugular vein, the portal blood is poor in cells

[1] In the solid constituents alone of the serum, an equal quantity of albumen is found in arterial and venous blood. (*Lehmann.*)

and in solids generally. The cells are also partly flocculent, easily distorted, and soon become jagged after their removal from the body, are richer in hæmatine and poorer in globuline, and contain twice as much fat. The intercellular fluid contains a less quantity of a fatty fibrine; while the serum contains less solid constituents generally (especially albumen), but more fat and extractive matters and more salts than any other vessel. Biliary substances have not been found in portal blood, and sugar only seldom occurs.

2. The blood of the *hepatic vein* differs much from that of any other vessel. Compared with the portal vein, it is poor in water; as 3 to 4 during digestion, and as 5 to 12 after it. Its clot is voluminous, and easily falls to pieces; and it contains less serum, in the proportion of 15 to 34. It is far richer in both cytoid and colored corpuscles, the former presenting every variety of size and form, and the latter forming heaps of a purplish-red color. The cell-walls of the latter are also less easily destroyed than those of the blood generally (p. 163), and the proportional amount of moist blood-cells in the blood of the hepatic and the portal veins is as 317 to 141. The latter are, however, poorer in fat and richer in salts, and especially poor in hæmatine, or at least in iron (two-thirds as much as in the vena portæ), but somewhat richer in extractive matters. Still, they have a greater specific gravity, though lighter in relation to the serum, since the intercellular fluid is far more dense, and contains much more of the solid constituents (as 11.8 to 8.4). The latter is, however, either wholly deficient in fibrine, or only contains a scarcely perceptible trace of it; and contains less albumen[1] and fat, and much less salts, with considerably more extractive matter, including sugar.

3. The blood of the *splenic vein* has been analyzed in horses by Mr. Gray.[2] Compared with that of the jugular vein, it contains more water, iron and fat, and more albumen and fibrine. There is also less solid residue in the serum, which always presents a dark-reddish tinge, and the corpuscles are very much diminished.

c. The blood of the *placental vessels* contains but little albumen

[1] The serum of the blood of the hepatic vein contains but two-thirds as much albumen as is found in the portal vein. The remaining one-third received from the portal vein has probably been assimilated in the development of the blood-cells which abound in the blood of the hepatic vein.

[2] On the Structure and Use of the Spleen. London, 1854.

and fibrine (*Stas*), but a large amount of *serum-caseine.* Stas also found urea in this blood.

D. Zimmermann found the serum of the blood of the *veins* of the *lower extremities poorer in water* than that of the *upper* extremities.

E. The *menstrual fluid* is to be regarded, histologically, merely as a hemorrhage[1] periodically recurring from the interior of the uterus, and therefore as *pure blood.* It is, however, discharged *per vaginam* in a state of admixture with the mucus of the cervix uteri and the vagina, and therefore contains epithelial cells and cytoid corpuscles. (Fig. 109.) Jul. Vogel states that menstrual blood contains no fibrine. On the other hand, E. H. Weber found *coagulated* blood on the mucous membrane of a young girl who had committed suicide during the catamenial period. The fact that in ordinary circumstances the menstrual fluid does not coagulate, has generally been attributed to the action of the acid mucus of the vagina, and not to the absence of fibrine, the former holding the latter in solution. Certain it is, that where the menstrual flow is so increased as to constitute a pathological condition (menorrhagia), there is no deficiency either of fibrine or of coagula.

Pathological States of the Blood in certain Diseases.

1. *Inflammation.* The changes in the intercellular fluid in inflammation are these: 1. In all inflammations accompanied by a febrile reaction there is an *increase of fibrine* (hyperinosis), it ranging from 4.7 to 10.5 parts in 1,000 of the blood. The highest increase occurs in acute rheumatism and pneumonitis. It may be considerable when the inflammation is not extensive, as in erysipelas; but in each particular disease it is proportioned to the degree and duration of the inflammation. It is independent of the strength of the patient, and of the increase or decrease of the other solid constituents of the blood, occurring in the most decided anæmia or hydræmia, and as abundantly in meningitis and other acute cerebral diseases as in inflammation of other parts. 2. The *albumen* is somewhat diminished in inflammatory blood. The serum also frequently becomes turbid from the presence of separated albumen. (*Scherer.*) 3. There is less *chloride of sodium* in inflammatory than in normal blood, but the sulphate of soda and of potassa are increased.

The *red corpuscles* are diminished in violent inflammation (rheumatism and pneumonitis), but not in any marked degree unless other pathological conditions coexist to induce a simultaneous dimi-

[1] Those who maintain that this fluid is an exudation, or an effusion, overlook the fact that the blood-corpuscles can leave the vessels only after a rupture of their walls. See next chapter, on "Effusions" and "Exudations."

nution of the whole mass of blood-cells. In some cases scarcely any diminution is observed. Still, the *carbonic acid* in the red corpuscles is increased in inflammatory blood, as are also the *colorless corpuscles;* and the former manifest an increased tendency to sink.

The diminution of the solid constituents of the blood is usually proportioned to the violence of the inflammation and the quantity of exudation thrown off. If there be but a small amount of the latter, they may, indeed, be rather augmented than diminished.

Finally, inflammatory blood *coagulates slowly*, and the clot usually presents the buffy coat (p. 93), and often the "cupped" appearance also.

2. *Fever.* Becquerel and Rodier found the blood in fever to be generally somewhat richer in water than in the normal state, and the phosphorized fats and cholesterine to be especially increased; while the phosphates are also considerably so. The blood-corpuscles are slightly diminished in number. Fibrine, extractive matters, and soluble salts occur in the normal amount. In simple *ephemeral* and *remittent fever*, however, the albumen, as well as the cholesterine, was increased. In slight *intermittent* fever they found the fibrine usually diminished, while Zimmermann found it usually normal. In *marsh fevers* the fibrine, albumen, and fats are diminished, and the blood-corpuscles are increased.

In *typhus* (also including typhoid) the blood exhibits no changes warranting us in regarding it as a dyscrasia. From the fifth to the eighth day it is very similar to that of plethora. From the ninth day it undergoes a great change, being specifically lighter, chiefly from a diminution of the corpuscles; though the solid constituents of the serum also diminish daily through the disease, with a rapidity proportioned to the intestinal affection. The salts and extractive matters are relatively increased, rather than absolutely diminished.

3. *Cholera.* In this disease the whole blood is especially dense and viscid. The fibrine is unchanged; the serum is denser, and poorer in water and salts. Relatively, however, it is richer in salts, and very rich in albumen. But it contains more potash salts, and phosphates than normal serum, with some urea, and an extractive substance which rapidly converts urea into carbonate of ammonia.

The blood-corpuscles are augmented—from 513 to 559 in 1,000 in men, and from 400 to 464 in women. (*Schmidt.*) This increase is, however, relative, since many blood-cells are actually destroyed. They are also poorer in salts, and their proportional amount of water is diminished (2.14 to 1.77). The proportion of organic to inorganic constituents is, however, increased—from 44.1 to 58.1. The specific gravity of the corpuscles is increased in men to 1102.6.

4. *Dysentery.* In this disease the corpuscles are fewer and lighter, their specific gravity being but 1085.5. The fibrine is usually increased, the solids of the serum decreased, especially the albumen, and the salts considerably increased.

5. In the *acute exanthemata* there is a diminution of the blood-cells, and increase of the intercellular fluid. The serum is denser than usual, and its salts more augmented than the organic substances.

6. In *puerperal fever* there is considerable diminution of the colored corpuscles; the fibrine is increased, is soft and gelatinous, and almost always forms a crust. In *most* cases the solid constituents are considerably diminished, though sometimes increased. Bile-pigment is occasionally, and free lactic acid not unfrequently, met with; the blood sometimes also having an acid reaction.

7. *Bright's disease.* The blood-cells and the constituents of the serum are diminished. The specific gravity of the former is often reduced to 1084.5. Cholesterine and the salts of the serum are, however, increased. On an average, there is more fibrine than in normal blood.

8. In *plethora* the blood-cells are rather more numerous, and the albumen is somewhat increased. In other respects the blood is nearly or quite normal.

9. *Hydræmic blood* is very much attenuated, pale, watery, and forms a loose, infiltrated, gelatinous clot.

10. *Anæmia.* The character of the blood depends much on the cause of the anæmia. In respect to the diminution of the blood-cells, it corresponds with the blood of hydræmia and chlorosis.

11. In *chlorosis* the blood forms a solid clot, covered with a buffy coat, and floating in a large quantity of serum. The corpuscles and iron are both diminished, in a small or an excessive degree, without any relation to the intensity of the disease. The fibrine is nearly normal; the albumen is increased only relatively to the cells.

12. In *leucæmia* the blood is pale red, often marked with whitish streaks, is rich in colorless blood-corpuscles (even one of these to three colored cells), and has an alkaline reaction, though the fluid filtered from the clot is acid. It contains true glutin, a body which ranks between glutin and albumen, hypoxanthine, and, finally, formic, acetic, and lactic acids.

13. In *pyæmia* the fibrine is diminished, and the colorless blood-cells augmented. This state is difficult to distinguish from leucæmia.

14. In *carcinoma* there is an increase of fibrine. The blood-cells are slightly diminished.

15. In *diabetes* there is simply an increase of sugar in the blood.

16. *Etherization.* The immediate effect of the inhalation of ether seems to be to make the blood richer in water and fat, and poorer in blood-corpuscles.

Finally, in regard to variations in the amount of particular elements of the blood in different diseases, the following may be regarded as established:—

1. The *fibrine* is *increased* (hyperinosis) in all inflammations and in carcinoma. An increase also occurs during the last months of

pregnancy. It is *diminished* (hypinosis) slightly in intermittent and marsh fevers, and in pyæmia.

2. The *albumen* of the blood is *increased* in plethora, in intermittent fevers, after drastic purgatives, and in cholera. It is *diminished* in simple ephemeral fevers (slightly), in severe inflammations, in the later stages of typhus, in scurvy, malaria, puerperal fever, dysentery, Bright's disease, and dropsy from organic affections.

3. The *extractive matters* are increased in puerperal fever and scurvy.

4. The *salts* of the serum (and especially the chloride of sodium) are *increased* in all cases in which the *albumen is diminished* (*Schmidt*); hence in dysentery, acute exanthemata, Bright's disease, typhus, and especially in dropsy. They are *diminished* in inflammation, and still more so in cholera.

5. The *colorless corpuscles* are increased in inflammation, leucæmia, and pyæmia, and after repeated losses of blood.

6. The *colored corpuscles* are *increased* in plethora, in cholera, in the first stages of heart-disease and the first eight or ten days of typhus, and in marsh fever. They are *diminished* in violent inflammations, in dysentery, anæmia, the last stages of typhus, in hydræmia, chlorosis, puerperal fever, acute exanthemata, Bright's disease, carcinoma, and scurvy. Their specific gravity is increased in cholera (to 1102.6), and diminished in albuminuria (to 1084.5) and dropsy (to 1081.19).

The number of the red corpuscles is also diminished by prolonged *fasting*, and extreme losses of blood or of other fluids; while the plasma becomes poorer in albumen and other organic constituents, but richer in salts; the whole blood becoming much the same as in anæmia. Similar results are, moreover, produced by substances interfering with digestion, or the formation of blood, especially the preparations of lead, acids, &c.

CHAPTER II.

SEROUS SECRETIONS, TRANSUDATIONS, AND EXUDATIONS.

SECRETION implies a separation of certain elements from the blood by the direct action of cells. It is, therefore, a vital action, and not dependent on mere physical agencies. In the case of secreting membranes, the secreting cells always constitute an epithelium upon its free surface. By the bursting of the secreting cells,

the contained fluid is set free, and is then recognized as the proper secretion of the surface on which it is found.

Transudation, on the other hand, is merely a physical phenomenon, dependent upon the permeability of membranes, by certain elements of the blood contained in their vessels; and must not be confounded with the vital process before defined. The word effusion is sometimes used to express the same phenomenon.

Exudation is also a vital process, as will appear.

I. The Serous Secretions.

Lehmann has included all the serous secretions under the head of transudations. This is, however, incorrect, since it has been proved that the normal serous secretions are separated from the blood by the epithelial cells of the serous membranes. The serous surfaces are, however, very liable to transudations also; and in all cases where an excessive amount of fluid is accumulated in a serous cavity, a transudation (or an exudation, which consists of the blood-plasma very nearly), directly from the blood, has occurred, and become mixed with the proper secretion; *e. g.* in ascites from pressure of abdominal tumors, the accumulation is almost exclusively from transudation, and very slightly from the natural secretion.

The proper *serous secretions* are, therefore, the fluids normally found upon the various serous membranes, viz., on the pleura, peritoneum, pericardium, the cerebral layer of the arachnoid, and the membrane lining the ventricles of the brain. To these may also be added the aqueous humor of the eye, the liquor Cotunnii, and the endolymph of the internal ear. The liquor amnii is a serous secretion; but, apparently, to a still greater extent, also a transudation. The synovial are incorrectly termed serous membranes, and their secretion is intermediate between the serous and the mucous secretions.

None of the serous secretions contain histological elements, excepting fragments of the epithelial cells (or still perfect ones) which secreted them. Molecular granules or cytoid corpuscles are merely accidental constituents, when present.

In fact, the serous are the simplest of all secretions. They approximate more or less nearly to the serum of the blood; while other secretions contain elements peculiar to themselves, which they have formed from the blood-plasma. It is, indeed, for this reason that physicists would regard them as mere transudations. Still,

they are not identical in composition on all the serous membranes, but vary to suit the requirements of each; *e. g.* the fluid of the ventricles of the brain contains the least albumen of all (0.5 per cent.), that of the peritoneum 1 per cent., and that of the pleura the most of all (1.8 per cent.). Albumen is entirely wanting in the aqueous humor, and in the liquor amnii during the last months of pregnancy. (*Lehmann.*) But to the physiologist the idea that this adaptation of the fluid to the requirements of the surface is delegated to a mere physical force, is, *à priori*, in the highest degree improbable, were there no facts to disprove it.

It is impossible to ascertain the normal *quantity* of the serous secretions, their amount is so small. Much of the fluid found after death in the serous cavities is a mere transudation, doubtless, occurring during the last moments of life.

Origin.—From the epithelial cells of the serous membranes, as already described.

Uses.—The serous secretions are merely for the prevention of friction of the opposed surfaces of the serous membranes. In the eye and the ear they evidently conduce to the perfection of the senses of sight and hearing.

II. Transudations.

It has been already stated that mere transudations are very liable to occur on serous surfaces, and these also are very similar in composition to blood-serum. Indeed, the true serous secretions being normally in so small amount that enough for analysis can hardly be obtained, the analyses of serous secretions (so called) are usually those of transudations, mixed with a very small amount of the former. In all cases when the secretion is abundant we may assume that the major part is a transudation merely. And, except in a few instances, transudations are to be regarded as pathological, while the serous secretion is physiological.

The transudations which may be regarded as physiological are the serous fluid in the areolæ of areolar tissue, the halitus from the lungs, and a certain amount of fluid also given out on the skin, independently of the true perspiration.

The pathological transudations include all cases of simple œdema, and of dropsy (ascites, anasarca, hydrothorax, hydrocephalus, hydrocele, hydrops articuli, ovarian dropsy, &c.). Colliquative sweats, diarrhœas, and the discharges in cholera must be also referred to

this head; and the hydragogue effects (so called) of certain cathartics.[1]

Transudation results, as a *physical necessity*, whenever bloodvessels are exposed very near to a surface in contact with the air, as is the case with the air-passages and the skin. But the state of fulness of the vessels, and the rapidity of the circulation through them, as well as the physical and chemical character of the blood itself, also exert a controlling influence on the amount of fluid transuded. The fuller the vessels, and the slower the motion of the blood-current, the greater is its amount. Hence congestion of the vessels of a part is a common cause of transudations; *e. g.* diarrhœa from portal congestion. And since congestion is often produced by pressure on venous trunks, the latter is commonly accompanied by œdema, anasarca, or ascites; as, in case of the last, from abdominal tumors, ovarian or otherwise. That the accumulation in such cases is not secretion merely, is evidenced by the fact that it amounts in some instances to 2 or even 3 pounds per day.

Transudations, like serous secretions, very nearly resemble the blood-serum in chemical composition, and, like them, they also normally contain no fibrine. But since animal membranes are more easily penetrated by water than by the other constituents of the blood-serum, next by the extractive matter and soluble salts, and then by albumen, it follows that transudations will contain more water proportionally to the solids than blood-serum does, and more salts in proportion to their albumen.

The quantity of *albumen* in transudations varies exceedingly. Lehmann states that it mainly depends on the following circumstances:—

1. Certain systems of capillaries transude more than others; *e. g.* those of the pleura most of all, and those of the ventricles of the brain least of all.

2. The slower the blood-current in the capillaries, the richer in albumen is the transudation; *e. g.* more albumen is found in peritoneal transudations (ascites) when dependent on pressure from large tumors than when caused by less disturbance of the circulation, as by cirrhosis of the liver.

3. The poorer the blood is in albumen, the less appears in transu-

[1] Lehmann also adds hydatids, and vesicular eruptions on the skin from any cause, to this list.

dations. Hence they contain little albumen in Bright's disease of the kidney.

The *salts* in the transudations are most abundant when the blood is richer in water; though they are always less, proportionally, than in the blood-serum, except in some cases of Bright's disease. The chlorine and potassium compounds predominate over the other soluble salts, in the transudations as well as in the blood-serum. In cholera, or after the administration of drastic purgatives, the quantity of salts is five or even seven times as great as that of the albumen; these transudations being, at the same time, richer in water than any other fluid in the organism.

Fibrine is said by Lehmann to be present in some morbid transudations, and which are termed fibrinous transudations by Jul. Vogel. We should, however, term a fluid containing fibrine in the circumstances supposed, an *exudation*, and not a mere transudation. If blood-corpuscles appear in a transudation, laceration of the minute vessels must also have occurred.

But little of the neutral and saponifiable *fats* is found in the transudations. The non-saponifiable fats (cholesterine and seroline) are far more abundant. The former, especially, is often very abundant in the fluid of ovarian dropsy and of hydrocele. It often abounds, also, in those from the ventricles of the brain, and from the peritoneum and pleura.

Bile-pigment and urea are also found in transudations; and sugar, in cases of diabetes.

The *quantity* of the transuded fluids varies greatly in pathological conditions, between the least perceptible increase of the normal transudation or secretion and the highest extremes. In a case reported by the author, 103 pounds of transuded fluid were removed from the peritoneal cavity; the patient (a female) being 63 inches in circumference.[1]

Uses.—The normal transudation in the areolar tissue gives it its required fulness and suppleness; while the halitus of the lungs and the transudation of the skin aid incidentally in preserving a moist condition of the pulmonary mucous membrane and the external integument. The rest are merely pathological phenomena.

[1] American Journal of the Medical Sciences, Jan. 1856.

III. Exudations.

Exudation has been very often confounded—and especially by chemists—with mere transudation; from which, however, it is widely different, both histologically and physiologically. Lehmann, however, admits that while transudation is the result of mere physical agencies, as has been explained (p. 182), exudation is due to vital power. But he limits exudations to inflammation as their producing cause, and admits that their *organizability* distinguishes them from mere transudations.

We cannot restrict the idea of exudation to the inflammatory process alone, however. We equally find organizable elements separated from the blood in cases where there is no inflammation; and we cannot apply to such cases the term transudation, any more than we can in case of inflammatory exudations. *Any organizable fluid spontaneously separated from the bloodvessels, without rupture of their walls*, is an exudation, whether it be in the case of repair (in wounds, &c.) without inflammation, or in cases of actual inflammation.

Exudations differ from transudations—*first*, in regard to the circumstances in which they are formed; and, *secondly*, in respect to their constituents.

1. Transudations are the result of physical agencies merely, and occur upon the natural free surfaces more especially, and while their epithelium is still in a normal state, and in the areolæ of the areolar tissue (p. 181); escaping, also, as Wedl suggests, through the walls of the veins. Exudations occur in consequence of some modified action of the vital force, and directly from the capillaries; and if upon natural free surfaces, in consequence usually of inflammation or irritation of the same. They also elevate and detach the epithelium, as is seen in case of vesicular diseases of the skin. But exudations also occur—and not transudations—upon free surfaces artificially produced; as in case of wounds, with or without loss of substance. In all cases, indeed, in which repair takes place, or in which new formations (false membranes, indurations, &c.) are produced, exudations occur; and it is by their organization that the repair or the formation of the new tissue is secured. Moreover, in normal nutrition an exudation of the plastic elements of the blood occurs in the substance of the tissues, and from which the latter are nourished. But this topic is included under the subject of nutrition;

though the fact shows that *stasis* of the blood is not necessary to exudation, as some have maintained.

2. It follows, therefore, that exudations differ from transudations in their constituents, since the latter are not organizable, and therefore cannot become the medium of the reparative process, nor be converted into adventitious growths in cases of inflammation. In exudations a considerable amount of fibrine is almost always present;[1] an element always wanting, we believe, in mere transudations (p. 183). There is also far more albumen in exudations, and the phosphates and potassium compounds are more abundant. Blood-corpuscles, more or less altered, are also often found in fresh exudations; but they are not an essential constituent, and depend upon a rupture of the minute vessels of the part. Sometimes, also, the exuded fluid, in case of inflammation, is stained by the hæmatine which has been dissolved out of the blood-corpuscles stagnant in the inflamed part. Exudations, indeed, approximate more nearly to the blood-plasma, and transudations to the blood-serum merely. But the latter are never precisely identical with the serum; and exudations abound far more in water and in the phosphates than does the liquor sanguinis, while they contain less fibrine.

Thus it appears that no histological elements exist in pure exudations when first separated from the blood, though the former are soon developed in them, unless the exudation is promptly reabsorbed, as will appear.

Origin.—Exudations are poured directly from the bloodvessels of the part; and as they normally contain no blood-corpuscles, no rupture of the vessels is required for their effusion, any more than in the case of transudations. The exudation in an incised wound is entirely free from blood-corpuscles, and occurs after all hemorrhage ceases. Exudation is not, therefore, a modification of secretion, no cell (epithelial or otherwise) nor other special structure being required for their production. In inflammatory exudations, blood-corpuscles are frequently also found, since rupture of the vessels, and consequent hemorrhage, is a very common concomitant of inflammation. It is in accordance with a vital law of the organism that *where new material for repair is required, or wherever an inflammation occurs, an exudation is poured out from the vessels of the part.*

[1] Lehmann states, however, that *plastic* exudations sometimes occur without fibrine (vol. ii. p. 290). Non-plastic exudations also contain it.

Uses.—The use of the normal exudations is explained in the preceding sentence, since they alone afford the materials for the reparative process. Inflammatory exudations are, however, to be regarded as pathological, and are almost always productive of only mischief.

Varieties of Exudations.

Exudations differ much in different circumstances, in respect to the properties of their chemical constituents; but the only varieties necessary to be mentioned here are the *euplastic*, or highly organizable, and the *cacoplastic*, or imperfectly organizable. Inflammatory exudations are always cacoplastic; and non-inflammatory exudations are so also in unfavorable circumstances, especially when the blood is impoverished. In favorable circumstances, and in which exudations are required—as in incised wounds—the latter are euplastic. Plastic exudations contain more fat than those not so.

Mr. Paget's division into the *fibrinous* and the *corpuscular* exudations has reference to the forms of organization occurring in them, and which may or may not be due to original differences in their constituents, as will appear under the next head. All pure exudations at first manifest the transparency and other physical properties of the liquor sanguinis, as has been already stated. The physiological and histological differences between the inflammatory and non-inflammatory exudations, as shown by their subsequent organization, will next be explained.

Changes occurring in Exudations.

Exudations, whether inflammatory or not, generally become coagulated soon after their separation from the vessels, and then promptly present the fibrillated appearance already described. (Fig. 49.) They may subsequently be (1) reabsorbed, or (2) may be organized into a new tissue; or (3) may be converted into pus.

1. *Absorption* of an exudation may occur either before or after coagulation. In almost all cases it is desirable that *inflammatory* exudations be reabsorbed as soon as possible, since only swelling of the part and other mischiefs result from their presence. The exceptions to this proposition are very few, and will be insisted upon by those only who still maintain the doctrine—never sustained by proof of any kind—that inflammation and the reparative process are identical. *E. g.* it is never desirable that the plasma exuded in

the cavity of the pleura, or the pericardium, or in the substance of the lungs, or in pleuritis, peritonitis, or pneumonitis, should remain; the sooner it is reabsorbed, the better. In case of non-inflammatory exudations, however, it is usually desirable that they remain and become organized into new tissue, since they alone afford the materials for repair. We should receive the idea of J. Vogel, that a coagulated exudation is dissolved, before reabsorption, by another exudation, called the "solvent," with doubt.

2. Either inflammatory or non-inflammatory exudations may become *organized;* the latter into tissues more nearly resembling the normal, since they, when normal in composition, are euplastic. In case of the inflammatory exudations (which have been most studied), coagulation of the fibrine is always the first step towards organization, the fibrillation becoming more distinct than it is in the normal coagulation of healthy blood; and exudation-cells and glomeruli (Fig. 59) being subsequently developed among them, if permanent new tissues are to be formed. Thus indurations, false membranes, &c., are produced as sequelæ of inflammations. On the other hand, euplastic (non-inflammatory) exudations are organized into tissues more nearly resembling the original, as in the healing of wounds by adhesion or "first intention." This form of organization is, therefore, to be regarded as an ascending metamorphosis of the exudation. It, however, when occurring on mucous membranes, proceeds no further than fibrillation, and to the subsequent development of cells, perhaps. The false membrane (so called) in croup never becomes vascular; and therefore, since it has no constant supply of nourishment from the blood, is always spontaneously detached if the patient's life is prolonged. But in case of inflammation on serous membranes, well-organized false membranes are frequently found, as will appear. (Ch. XI. Sect. IV.)

3. Both kinds of exudations are liable to become converted into corpuscles, instead of fibres, and then into pus. Especially is this the case if they are exposed to the action of the atmosphere. In this case, exudation- or pus-corpuscles are usually developed in the exudation, without any previous coagulation; and hence Paget terms it the corpuscular, and Rokitansky the croupous exudation. It usually contains more fat, and the fluid part is mostly absorbed after the corpuscles are formed. The formation of pus in an exudation is sometimes said to be characteristic of the "suppurative inflammation." It is, in fact, mere *suppuration*—*i. e.* the production

of pus—and not inflammation itself, nor necessarily dependent on inflammation in any sense. The corpuscles first formed are sometimes called "exudation-corpuscles," as if peculiar to exudations. They are, however, merely the cytoid corpuscles already described (p. 145), and are developed in accordance with a law stated on page 146. That they are also here histologically (though not physiologically) identical with pus-corpuscles, will be shown under the characteristics of pus.

Whether an inflammatory exudation is to become organized into fibres and tissues, or into corpuscles (pus) merely, depends mainly upon three circumstances (*Paget*):—

1. The *condition of the blood*, and therefore the composition of the exudation itself. Hence empyema is more common as a result of pleuritis in scrofulous and other debilitated subjects, and adhesions in the more robust. (p. 94.)

2. *The seat of the inflammation.* If this be on serous membranes (as the pleura), fibrillation and false membrane are common; if the tissue of the lung itself is attacked (pneumonitis), the exudation first coagulates (forming the *red hepatization*, as it is improperly called), and is then converted into pus, which, by an equal misnomer, is termed the "gray hepatization." In true croup, the exudation first fibrillates, and subsequently, if sufficient time is given, is developed into pus, the fibres being previously dissolved. Hence, in an abscess containing pus, fibres are also frequently found intermixed, especially in the portions of pus first formed.

3. The *intensity of the inflammatory process* affects the organization of the exudation by modifying its plasticity. The more intense the former, the more liable is the latter to be developed into pus.

While the organization of exudations into tissues is an ascending metamorphosis of the former, their conversion into pus must be regarded as an abortive attempt at the same. The pus-corpuscle is, histologically, identical with the exudation-corpuscle, and not a degeneration of the latter, as has been asserted. It is merely an *arrest of development of the exudation-corpuscle.* Exudation-corpuscles normally form cell-walls around them, and then develop the higher tissues; and hence the exudation (cytoid) corpuscles become, in fact, the nuclei of *exudation-cells*, of which less notice has been taken. Hence Gluge regards pus-corpuscles as *nuclei*, "because in granulations and the formation of cicatrices it is readily and directly conclusive that cells form upon pus-corpuscles; for the nuclei of young cicatrix-cells, in appearance and chemical relations, are perfectly identical with the latter."[1] We would say, exudation-*cells* form upon exudation-corpuscles, the latter being the nuclei of the former; while the pus-corpuscles are merely the exudation-corpuscles, arrested in their development, and destined not to rise to

[1] Pathological Histology, p. 45.

any higher organization. Pus is totally aplastic, and its corpuscles possess a very low vitality.

Origin and Characteristics of Pus.

Thus pus is not a secretion, but is a *changed exudation;* the change being due to various causes, among which the action of the atmosphere is one of the most prominent. In granulating wounds, therefore, we find a pure exudation constantly appearing on the surface of the living tissues, with exudation-corpuscles and cells forming in it; while the external portion of the exudation has become true pus. All the intervening grades of development between these two extremes will, of course, present themselves. Flakes or fibrillæ of coagulated fibrine will also be often found mixed with the pus first formed in an abscess; these having been formed by simple fibrillation as the initiatory step, and before the pus-corpuscles are developed. It is also certain that pus may be formed from a solid mass of fibrine after its coagulation. (*Vogel.*)

Thus, also, it appears that pus is formed from an exudation by a "retrogressive metamorphosis." (*Wedl.*)

Characters of Pus.

Pus, when perfectly formed—genuine pus—is a yellowish, creamy, thick fluid, of a specific gravity of 1030 to 1033 (*Gluge*), and a feeble alkaline reaction. Exposed to the air, however, it soon undergoes transformations; passing into the acid fermentation, or the alkaline, or into putrefaction. In cases of phthisis, pus is sometimes acid when expectorated.

The whole amount of solid constituents in pus is 140 to 160 parts in 1,000, of which only 5 to 6 per cent. consists of mineral substances. Of the last, the soluble salts predominate, being proportioned to the insoluble as 7 or even 9 to 1. It also contains the oxide of iron.

Seen under the microscope, pus consists of (1) a fluid portion, containing (2) histological elements—the pus (cytoid) corpuscles. An analysis of pus, as compared with that of the blood, shows the former to contain far less albumen, no fibrine at all, far more fat, and about three times as much chloride of sodium, the latter being confined almost exclusively to the pus-serum. Fibrine, whether coagulated or not, is sometimes found *mixed* with pus, however; a portion of the exudation still remaining unchanged. "Connective tissue-cells" (nucleated fibres), may also be found in pus, from a higher organization of a part of the exudation. (Fig. 104.)

1. The *fluid portion* (pus serum, or liquor puris) is perfectly clear, colorless or slightly yellowish, has a feeble alkaline reaction, and coagulates, on being heated, into a dense white mass. Its main constituent is albumen, which constitutes from 12 to 37 parts in 1,000. Some of the fat in pus also belongs to the serum, and about 1 per cent. of cholesterine.

Fig. 104.

Exudation-cells and nucleated fibres in pus. *a.* Large granulous exudation-cells. *b.* Pus-corpuscles. *c.* Nucleated fibres. *d.* Pus-corpuscles, their nuclei being brought out by acetic acid. *a'.* Granular exudation-cells after action on their nuclei of water.

Mucosine (*pyine*), and *caseine*, are only abnormal constituents of pus-serum (*Lehmann*), as are also bile-pigment, resinous bile acids, urea, and sugar. It is the mucosine which forms the filaments seen in Fig. 107. It was called *pyine* by Güterbock.

2. Accidentally, blood-corpuscles, epithelial cells, exudation-cells, and fragments of tissues (Fig. 105) may be found in pus; but the only normal histological element is the cytoid (pus) corpuscle, except occasionally minute fat-globules.

Pus-corpuscles (Fig. 106) have already been described under the head of cytoid corpuscles (p. 146), they being vesicles consisting of a cell-membrane often appearing granular, with a nucleus adhering to it, and viscid hyaline contents. They average

Fig. 105.

Fig. 106.

Fig. 105. Other histological elements, in pus, in an incipient state of fatty degeneration. The granular corpuscles (*a*) are pus-corpuscles; the open rings (*b*) with borders are red blood-corpuscles; the sharply-defined circles are fat-globules. Two epidermic cells (*c*), with an oval nucleus are also seen, and a coagulated mass with molecules (*d*). (*Wedl.*)

Fig. 106. Pus-corpuscles. *a.* Natural appearance. *b.* After acetic acid.

from $\frac{1}{3000}$ to $\frac{1}{2400}$ of an inch in diameter, being usually larger than the cytoid corpuscles of the blood, and smaller than those of saliva. They, however, vary in different circumstances, being all small in an abscess, and all large in a wound. (*Vogel.*) They also vary in appearance in different states of the organism—as in phthisis, in typhus, and in the cancerous dyscrasia. (*Lehmann.*) Besides,

their size varies, on account of their endosmotic properties, with the specific gravity of the pus-serum, they being contracted and smaller as the latter increases, and *vice versa* (p. 145).

The investing *membrane*—sometimes wanting in the smaller corpuscles (*Wedl*)—is an albuminous ("proteine") compound, but is not fibrine. (*Lehmann.*)

The *nuclei* of pus-corpuscles are $\frac{1}{3636}$ to $\frac{1}{4615}$ of an inch in diameter (*Wedl*), and also appear to be an albuminous substance. If they had been originally visible, they are usually of a lenticular form, and these are probably the mature corpuscles. In case they are invisible at first, they are subsequently found to be tripartite, and of a sharply-defined outline. This latter appearance, usually produced by a change in the chemical reaction of the pus after its formation, has been thought to be characteristic of pus-corpuscles. It has, however, been already explained (p. 146).

The *contents* of the pus-corpuscles are also principally albuminous compounds. (*Lehmann.*) The fat of pus (20 to 60 parts in 1,000) is contained, in great part (about two-thirds), in the corpuscles; and the granules are probably composed of it, in part at least.

In regard to the precise manner in which pus-corpuscles are *formed*, nothing special need be remarked here, they being developed from minute granules into larger corpuscles—the nuclei—as Vogel has shown, and around which the cell-wall subsequently appears; it being at first transparent, and afterwards granular. They, like all other cytoid corpuscles, are first formed by free cell-development. But they may, doubtless, be subsequently developed from the pre-existing corpuscles, and thus pus propagates itself. Hence the importance of seasonably evacuating a cavity containing pus; or of destroying the pus-corpuscles, as by the application of caustic, &c., as in the treatment of ophthalmia and blennorrhœa.

It is a practically important question, How long a time is necessary for the development of pus in a fresh exudation? Lehmann states that in exudations "not perfectly fresh, obtained from subcutaneous wounds with loss of substance," in the lower animals, granules and nuclei, constituting the beginning of the suppurative process, appear in "about half an hour." Gluge says that in "twelve hours after a blister is applied to the surface of the human body, the exudation has become slightly turbid from the presence of pus-corpuscles, many of which already have a clear border to one-half of their circumference, which is the future cell-wall in the course of development." The process of development still continues, even if the exudation be removed from its contact with the body. Indeed, in the clear exudation, when removed from the surface, "perfectly spherical cells with nuclei were developed after several hours" (p. 46). Helbert had before asserted that cells may form in a plastic liquid removed from the body.

In the case of a blister, we may, therefore, conclude that true pus may be formed in less than twenty-four hours. A longer time,

however, than forty-eight hours is required for its development in case of wounds; and more frequently at least seventy-two to ninety-six hours elapse before suppuration is established in case of surgical operations in adults. It is, however, more promptly established in children, and in the warmer season of the year.

Genuine pus is a bland fluid, and does not dissolve the tissues in contact with it; but only destroys their vitality, if at all, by pressure. It is thus that the articular cartilages may die in case of suppuration in bone in contact with them. Morbid pus, however (sanies, &c.), is highly corrosive, and rapidly dissolves the tissues. Decomposed pus may also produce the same effect.

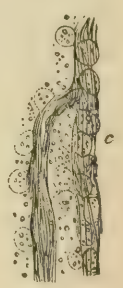
It is not necessary here to speak of the *pathological* conditions of pus, any further than to remark that the pus-corpuscles (like all other cytoid corpuscles) are liable to fatty degeneration; strongly-defined fat-globules appearing within them, as in Fig. 105. The serum also then contains more fat than usual; and finally the characters of the pus-corpuscles are lost, only scattered molecules remaining in their stead.

In connection with pus, Wedl mentions a peculiar histological element, occurring most frequently and in the greatest abundance in the sputa of pneumonitis. It is a finely-granular globule, $\frac{1}{1500}$ to $\frac{1}{6000}$ of an inch in diameter, with a sharply-defined cell-wall of a yellowish or yellowish-brown color, sometimes containing scattered pigment-granules, and entirely destitute of a nucleus. Fig. 107 shows four of these bodies, mixed with pus-corpuscles and

Fig. 107.

Granular globules (sterile cells), without nuclei, in the grayish-yellow sputa of pneumonitis. The smaller cells are pus-corpuscles, and the lines represent filaments of mucosine. The sterile cells are filled with occasionally pigmented contents. (Magnified 350 diameters.) (*Wedl.*)

Fig. 108.



Sputa of acute pneumonitis, containing fibrinous casts of the minute bronchial tubes, large cells filled with oil-globules, and finely-granular cells resembling pus-corpuscles.

filaments formed by the mucosine from the sputa above mentioned. They may perhaps be abortive glomeruli or granule-masses, and hence Wedl terms them "sterile cells." Another form of sputa in

acute pneumonitis, containing casts of the tubes and cells filled with oil-globules, is shown by Fig. 108.

Finally, pus cannot be absorbed from a part without disintegration of the corpuscles, and then reappear in another part, as some still maintain. It may enter the blood through openings in the vessels (as in stumps, &c.), but in no other way.[1]

Uses of Pus.

1. Pus, being a bland fluid, is incidentally useful when formed upon granulating surfaces, in protecting the subjacent layer of the exudation from the action of the air, and thus enabling it to be organized into tissue instead of pus. The granulations themselves also would be reabsorbed, and the reparative process arrested, if the air were not thus kept from them. It follows, therefore, that whenever it is impossible to exclude the air from a granulating surface by artificial means, the pus should not be entirely removed when the dressings are renewed; but only any excess, or any portion which has undergone or may soon undergo decomposition. Here, then, pus is incidentally useful; though its formation—*i. e. suppuration*—is not desirable, were it possible to secure the organization of the whole of the exudation into new tissue.

2. Again, when an exudation has become coagulated in a part, or on a mucous membrane, it is sometimes better that it should be organized into pus than into tissue, provided it cannot be reabsorbed; for then it may be removed from the part. *E. g.* in pneumonitis the exudation had better become developed into pus-corpuscles and fatty molecules (gray hepatization), and be removed in the sputa, than become organized into an indurated mass, destroying the pulmonary structure. And if the exudation in true croup is converted principally into pus and removed by the act of coughing, instead of taking the form of a tough false membrane, so much the better for the patient. In such cases, therefore, the formation of pus is an advantage; in other terms, *suppuration* is an advantage, though the pus itself is of no use in the organism.

3. On the other hand, suppuration is always directly *destructive* of the exuded plasma—*i. e.* it prevents the latter from being organized into tissue. Hence profuse suppuration produces a powerful exhausting effect upon the organism, unless neutralized by an abundance of nutritious food. The emaciation which it also produces is easily explained by the abundance of fat in pus, there being, on an average, at least ten to fifteen times as much, proportionally, as in the blood. Hence the use of cod-liver oil seems to be indicated here as well as in scrofula and phthisis. It also follows that in all cases of repair

[1] Vogel mentions a case of empyema in which a thick creamy fluid escaped in the urine when the thoracic effusion subsided. The microscope, however, showed that the urinary admixture consisted entirely of epithelial debris.

by granulation we should, by excluding the air by appropriate dressings, and by all other possible means, reduce the amount of pus to the *minimum*.

The preceding is believed to be the view of the subject of transudations, exudations, and the formation of pus, which the present state of science demands. In regard to the first two subjects, it must, however, be admitted that much still remains to be ascertained and settled. Only well-marked transudations on the one hand, and exudations on the other, have been here discussed. But all possible transitional forms between the two are found to exist; there being sometimes a transudation with a small amount of exudation added to it, and at others precisely the reverse. We may also have a transudation, as well as an exudation, mixed with pus; and herein lies the essential difficulty in investigating these subjects. In conclusion, we must confess, therefore, with Wedl, that "our present doctrine with respect to exudation [and transudation] is but a very poor crutch, upon which we must hobble for a time, in order, in some degree, to obtain a measure of the field we have to survey" (p. 38).

CHAPTER III.

THE MUCOUS AND THE GLANDULAR SECRETIONS.

The glandular are here associated with the mucous secretions from the fact that the ducts of all true glands are lined by a mucous membrane, which secretes some of the varieties of mucus in a part of its extent, while its epithelial cells in the smallest subdivisions of the ducts elaborate the secretion characteristic of the gland. It consequently results that all the true glandular secretions contain an admixture of mucus, to a greater or less amount; and hence the mucous secretions will be first described, under the head of "Mucus."

SECTION I.

MUCUS.

It has been supposed to be a sufficiently accurate statement that mucus is the fluid normally secreted upon the mucous membranes. While, however, we have a definite idea of a mucous membrane as

always containing the same histological elements, it is by no means true that precisely the same secretion is afforded by them all. The ultimate ramifications of the ducts of all true glands (salivary glands, kidneys, &c.) are lined by a mucous membrane, though their secretions widely differ from each other, and are in no case true mucus. It is more accurate to say that the epithelial cells alone of the membrane secrete. But here again we must exclude the epithelial cells of the minutest gland-ducts in specifying the structure concerned in elaborating mucus.

Where, however, we find a mucous membrane, in other circumstances, is expanded as a protective structure (as in the alimentary canal, air-passages, &c.), we also find minute cavities sunk into its substance and opening upon its surface, and the epithelial cells of these are the actual secretors of true mucus. Doubtless, also, the epithelial cells upon the general level of the mucous membrane secrete mucus, but in a less degree.[1]

Mucus may therefore be defined to be the fluid secreted by the epithelial cells of the follicles and of the general surface of mucous membranes, except where they form the lining of minute gland-ducts.

It is, however, not true that mucus is always, in composition, the same fluid, even when restricted to these limits. It contains an immediate principle called mucosine; but it has already been stated (p. 84) that at least three varieties of this substance exist, to which as many different forms of mucus correspond. Indeed, it is clear that the same fluid would not answer the requirements on the different mucous membranes, or on all parts of the same one; hence the mucus of the mouth is very different from that of the nasal passages, and that of the cervix uteri from that of the uterine cavity and of the vagina. A more discriminating investigation of the different fluids termed mucus, because found on mucous membranes, is therefore demanded. *Physiologically*, mucous membrane has *no specific character, so far as it is secretive*, but only so far as it is *protective*.

Mucus is described as a viscid mass, capable of being drawn into threads, and consisting (1) of a pellucid, cohesive fluid, containing (2) a variety of morphological elements, principally epithelial cells.

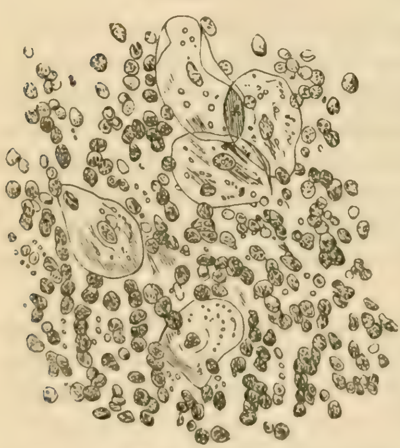
[1] Synovial *bursæ* (so called) also belong to this category, and secrete mucus.

1. The *fluid* portion alone of mucus is peculiar, and this alone is to be regarded as a secretion. Its chemical reaction varies; being alkaline, for instance, in mucus from the cervix uteri, while it is acid in that from the vagina. It contains only from 4.4 to 11.8 per cent. of solid matter, of which 0.7 per cent. consists of salts, the chloride of sodium being the most abundant.

2. The morphological elements are to be regarded as distinct developments, either formed or merely inclosed in the fluid portion. The epithelial cells belong to the latter category; the cytoid (mucus) corpuscles are developed in the true mucus, after its secretion from the blood, upon the mucous membrane (p. 147). The morphological elements, however, usually form a large portion of the whole mass. The epithelial cells are conoidal or otherwise in form, according to the particular membrane or part from which they are derived. The cilia usually become detached if the epithelia were ciliated.

Albumen does not exist normally in mucus, but occurs whenever the mucous membrane becomes inflamed. (*Julius Vogel.*) It may also occur in mere congestion; but in both of these cases results from transudation. Fat is abundant in catarrhal affections, in the form of vesicles or granules; there being, however, but very little in normal mucus. Molecular granules are most abundant in the white sputa of typhus. Coagula of fibrine and colored blood-corpuscles are often found on mucous membranes when inflamed (*e. g.* in croup); but here true mucus is no longer secreted, but an exudation has occurred instead. These coagula often form tubes lining the bronchia in bronchitis and pneumonitis. A mixture of mucus and blood-corpuscles and epithelial cells is shown by Fig. 109.

Fig. 109.



Mucus-corpuscles, epithelial cells, and blood-disks, in vaginal mucus. The epithelial cells are recognized by their comparatively very large size.

Granular masses and cells—inflammation-globules (p. 119), are also found, especially in case of inflammation of the air-passages. Some discover pus-corpuscles, also, in case of inflammation of the mucous membranes; but it has been already

shown that the latter are not to be distinguished, in their natural state, from the normal cytoid corpuscles in mucus (p. 146). Vibriones and microscopic fungoid growths must be considered as of incidental occurrence.

It should also be added that a fluid possessing all the characters ascribed to mucus is sometimes secreted in certain cysts.

The *quantity* secreted by the mucous membranes cannot be ascertained with accuracy. Valentin believed the amount to be exceedingly small, or even absolutely nothing, in the normal state. Certainly it is only in irritative congestion, or inflammation, that the amount becomes considerable; but then there is a transudation or exudation, or both, mixed with the true mucus.

Origin.—It has been stated that true mucus (*i. e.* the fluid portion) is secreted by the epithelial cells of the follicles or of the general surface of mucous membranes, except when they line the ducts of glands; while the epithelial cells of the latter secrete saliva, urine, &c., according to the gland in which they exist. It is, therefore, the *epithelial cells* on a mucous membrane, and not the mucous membrane merely as such, which manifest specific vital properties and specific secretory functions (p. 195).

It has been suggested that the true mucus is derived from a sort of decomposition or partial disintegration of the epithelial cells. Though this chemical view may be correct so far as it implies that mucus *as found* is different from the same while still inclosed within the epithelial cells, there are sufficient physiological grounds for the belief that mucus is, at any rate, originally elaborated within the epithelial cells, from the plasma of the blood. It might be anticipated that the form of the epithelium, whether scaly or conoidal, would correspond with a difference in the fluid secreted.

The *cytoid* (mucus) *corpuscles* are, by some, said not to be present in normal mucus. Kölliker maintains that they "are abnormal, but almost constantly present," in the mucus of the oral cavity; being a "kind of exudation or pus-corpuscle, with which they have the closest possible resemblance in structure" (p. 466). Lehmann seems rather to indorse the idea that the mucus-corpuscles, so called, are merely abortive epithelial cells.

While we agree with Kölliker that the cytoid corpuscles constitute no part of the true mucus, we cannot regard them as abnormal products; nor admit, on the other hand, that they have any developmental relation to the epithelial cells. We believe them to be

developed in the true mucus (probably from the mucosine especially), in accordance with the law specified on page 146. Hence, in case of irritation, congestion, or inflammation of the membrane, these corpuscles increase; since not only mucus is secreted, but (from the consequent transudation or exudation upon the membrane) albumen or fibrine (or both) is blended with it.

Uses.—True mucus is merely protective to the parts with which it is brought in contact. Some of its modifications, however—as the gastric and intestinal fluids—perform an important function in aid of digestion, as will appear (pp. 200 and 201).

From the relations of the mucous membrane to the true glands, which have been specified, it must follow that all the glandular secretions must contain an admixture with them, to a greater or less extent, of true mucus and mucus-corpuscles.

Varieties.—Three varieties of mucus have already been mentioned, viz:—

1. The mucus from the nares and bronchial tubes, the large intestine, and the interior of the uterus.

2. That from the neck of the uterus. This has an alkaline reaction, while that from the vagina is acid.

3. The mucus in the urine.

Other varieties still might be added, which differ not only in appearance, but also in the characters of the mucosine they contain.

Synovia, in its chemical composition, approaches nearer to the mucous than to the serous secretions. Tildanus always found mucosine in it, as well as albumen. The synovial bursæ also contain true mucus rather than synovia, and were by Bichat not inappropriately termed "bursæ mucosæ."

The remaining modifications of mucus, which require a particular description, are the gastric and the intestinal fluids.

The Gastric Fluid.

Pure gastric fluid is clear, liquid, colorless or slightly yellowish, of a peculiar feeble smell, a slightly saltish taste, and of a very acid reaction. It is a little heavier than water, and for a long time resists decomposition. No morphological elements belong to it, though the epithelial cells of the gastric follicles (favuli) and their nuclei, and a fine molecular matter, are found floating in it.

Gastric fluid, when filtered, contains only 1.05 to 1.48 per cent. of solid elements; of which 63 per cent. are organic, and 37 per cent. are inorganic matters.

The *organic* substance to which the gastric fluid mainly owes its property in aid of digestion, is called *pepsin.* It is closely allied to the albuminous compounds.

Fig. 110.

Gastric peptic glands. *a.* Common trunk. *b, b.* Its chief branches. *c, c.* Terminal cœca, with spheroidal gland-cells.

The *free acid* of the gastric juice is partly the hydrochloric and partly the lactic acid (p. 61). The former constitutes, on the average, 0.35 per cent., and the latter 0.45 per cent. of the fluid. The hydrochloric acid usually does not appear till some time after digestion has commenced. (*Lehmann.*)

Of the *mineral constituents* of gastric juice, the chlorine compounds are the most abundant. The chlorides of sodium, ammonium, calcium, magnesium, and iron are found in it.

Accidentally, also, iodide and ferrocyanide of potassium, salts of iron, and urea may exist in gastric fluid.

Experiments lead to the conclusion that dogs secrete in twenty-four hours an amount of gastric fluid equal to one-tenth their weight. This would give a range between 12 and 18 pounds for a man. Lehmann states, however, that, "according to several direct observations on a woman, as much as *one-fourth* of the weight of the body has been found to be secreted as gastric fluid"[1] !!! Of course this is all secreted directly from the blood, and the latter is estimated by Lehmann to constitute but *one-eighth* of the weight of the body. No further remark appears necessary upon his estimate of the gastric fluid.—The quantity is increased by aromatic substances, sugar, alcohol, and alkalies. It is not secreted at all during fasting.

Fig. 111.

Gastric favuli (alveoli), in the bottom of which the glands open. They are 1-200th of an inch deep, and 1-250th of an inch broad: the septa being 1-1000th of an inch wide.

Origin.—Gastric fluid is secreted by the epithelial cells of the peptic gastric glands (Fig. 110), as mucus is by the epithelial cells of other mucous membranes, as al-

[1] Chemical Physiology, p. 168.

ready explained. The gastric favuli, into which these glands open, are shown by Fig. 111.

Function.—It is by the agency of the gastric fluid that the albuminous compounds in the food are dissolved[1] and converted into uncoagulable substances, soluble in water and dilute alcohol, and which Lehmann has termed *peptones.* Mialhe first termed these substances *albuminose* (p. 87). It is probable that the acids are principally efficient in dissolving these compounds; while the pepsin, acting by catalysis, enables them to exert a vastly greater solvent power than they would without it. From 3 to 5 grains of coagulated albumen may be dissolved in 100 grains of recent gastric juice. It has no effect at all on the fats and other non-nitrogenized elements of the food, these passing through the stomach unchanged by it. Other strong mineral acids (but not the organic) may partially supply the place of the hydrochloric and lactic. Its digestive power is also increased by the addition of fat. Bile entirely suspends its digestive power, and saliva diminishes it.

The gastric fluid, however, is not sufficient to dissolve *all* the albuminous compounds necessary to nourish an animal.[2] (*Lehmann.*) Besides, it loses its digestive power in the duodenum, where its acid reaction is overcome by the alkaline bile and pancreatic fluid. Another fluid must therefore flow into the intestine, below the duodenum, which exerts a similar effect, and which will be next described.

The Intestinal Fluid.

Frerichs has ascertained that the glandulæ aggregatæ (Peyer's patches) contribute but very slightly[3] to the formation of the intestinal fluid—they being closed sacs—and that its true secreting organs are the pouch-like follicles of the small intestine (Lieberkuhn's follicles), and the similar larger and very numerous follicles of the large intestine. In chemical composition, the fluids of the small and the large intestine are found to be perfectly identical.

The intestinal fluid is a glassy, transparent, colorless, tenacious

[1] Bernard proves that while white fibrous tissue is dissolved, muscular fibre is merely softened, as if it had been boiled. Starch, sugar, and fat are not affected at all by the gastric fluid.

[2] This assertion is doubtless correct in itself, but not at all consistent with Lehmann's estimate of its quantity, mentioned on page 199.

[3] Not in the least, as will appear in the chapter on "The Alimentary Canal."

mass, with a strong alkaline reaction. (*Frerichs.*) Of course there must be more or less true mucus, in all cases, in combination with the secretion of the follicles. The morphological elements found in this fluid are conoidal epithelium-cells (these having secreted it), nuclei from the same probably, granular cells, and here and there a little fat.

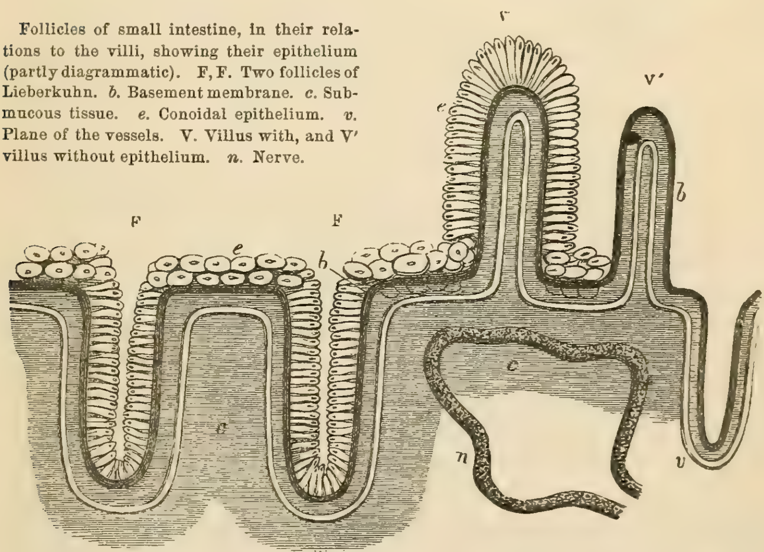
This fluid averages 3.2 per cent. of solid constituents, .195 per cent. being fat.

The *quantity* of the intestinal fluid cannot be accurately ascertained. Bidder and Schmidt calculate that about 9½ ounces are secreted in twenty-four hours by a man weighing 140 pounds. It is secreted in greatest abundance four or five hours after a meal, and is increased by drinks.

Origin.—The intestinal fluid is secreted by the epithelial cells of the follicles of the small and of the large intestine. (Fig. 112.)

Fig. 112.

Follicles of small intestine, in their relations to the villi, showing their epithelium (partly diagrammatic). F, F. Two follicles of Lieberkuhn. *b.* Basement membrane. *c.* Submucous tissue. *e.* Conoidal epithelium. *v.* Plane of the vessels. V. Villus with, and V′ villus without epithelium. *n.* Nerve.



Uses.—This fluid is proved, by the experiments of Bidder and Schmidt, to unite in itself the powers of both the gastric and the pancreatic fluids—*i. e.* it at the same time digests flesh and all albuminous substances, and also changes starch and prepares it for absorption. It has been seen that the gastric fluid loses its power as a digestive agent on arriving in the duodenum; and the pan-

creatic fluid is reabsorbed, and therefore disappears, by the time it reaches the middle of the small intestine. Other agencies are therefore required to complete the processes these two fluids have commenced, as the food passes lower down the canal; and these are apparently supplied by the intestinal fluid alone. It appears, moreover, that while bile suspends and the pancreatic fluid impedes the digestion of the albuminous compounds by the gastric juice, they do not at all interfere with that by the intestinal fluid.

SECTION II.

THE GLANDULAR SECRETIONS.

By the glandular secretions are meant those of the true or compound racemose glands, and whose ducts are lined by a prolongation from a mucous membrane. They, of course, all contain some admixture of mucus, and will be described in the following order:—

I. Milk.
II. Semen.
III. Glandular secretions discharged into the alimentary canal (saliva, bile, &c.).
IV. Urine.
V. The lachrymal fluid.

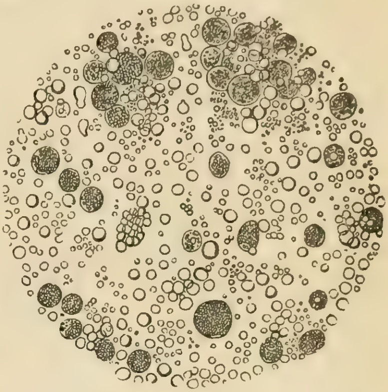
I. Milk.

Human milk is white, slightly translucent, colorless, of a weak sweetish taste, and of an alkaline reaction. Its specific gravity is between 1030 and 1034. After standing at rest for a time, a yellow layer abounding in fat (the cream) forms on the surface, while the fluid below becomes specifically heavier, and of a bluish tinge. It is not coagulated by boiling, but forms on its surface a film of coagulated caseine mixed with fat-globules. Rennet (*i. e.* the mucous membrane of the calf's stomach) coagulates it, as has already been explained in connection with the properties of caseine (p. 88). Exposed to a temperature somewhat above the mean, an acid is developed in it, and which precipitates the caseine, constituting the acid fermentation or "souring" of the milk.

The milk secreted for the first three or four days after parturition has peculiar characters, and is called *colostrum.* This is a turbid, yellowish fluid, resembling soap and water, viscid, and strongly alkaline in reaction. It contains more solid constituents than normal milk, and passes more rapidly into the acid fermentation. This

increase principally affects the sugar (to 70 parts in 1,000) in woman's milk, and the caseine in that of the cow. It also contains more fat than normal milk (even 50 parts in 1,000), this proceeding probably from the colostrum-corpuscles; and twice or thrice the amount of salts.

Fig. 113.



Milk-globules and colostrum-corpuscles, the latter being the largest.

Under the microscope, milk shows an immense number of fat-globules suspended in a clear fluid, and which are called the milk-globules. (Fig. 113.) For a short time after parturition it also contains the colostrum-corpuscles, some of which are also shown in the accompanying figure.

1. The *milk-globules* are from $\frac{1}{4000}$ to $\frac{1}{6666}$ (Hassal says $\frac{1}{4500}$ to $\frac{1}{4000}$) of an inch in diameter, being fat-globules surrounded by a special membrane of caseine, as already stated (p. 89).

The *colostrum-corpuscles* (granular cells) are irregular conglomerations of fat-granules, held together by an amorphous albuminous substance (homogeneous substance), being $\frac{1}{2000}$ to nearly $\frac{1}{500}$ of an inch in diameter, having no nucleus nor cell-wall. They occur not only in the colostrum (up to the third or fourth day after parturition, and sometimes even up to the twentieth), but always also when the milk-secretion is disturbed by any pathological condition. Precisely similar bodies also occur in inflammatory exudations, and are then called "glomeruli" and "inflammation-globules." (See Figs. 42 and 59.)

Epithelial cells often appear in milk; cytoid (mucus) corpuscles rarely—and in pathological states of the mammary glands. Fibrinous clots and blood-corpuscles, of course, occur only when hemorrhage into the lactiferous ducts has taken place. Infusoria (vibrio bacillus and byssus), as in the blue milk of cows, are very rarely observed.

2. The *fluid* portion of milk consists, on an average, of water 883.6 parts (*Simon*) to 1,000 of milk, holding in solution the following substances, and in the following proportions:—

	Water	883.6
1.	Caseine	34.3
2.	Sugar of milk (lactine) and extractive matters .	48.2
3.	Fixed salts	2.3

4. The butter (fat) is derived from the milk-globules, and makes up the remaining 25.3 parts in 1,000.

1. The amount of *caseine* in woman's milk is greater after animal than after vegetable food. It is, however, less abundant than in cow's milk, the latter containing 41.6 (*Playfair*) in 1,000. The coagulum is also less dense, and therefore more easily digested by the infant. L'Heritier found over 50 per cent. more caseine in the milk of the brunette than in that of the blonde.

2. Woman's milk contains more *sugar* than that of the cow; the latter containing 34 to 43 in 1,000. L'Heritier also found that the milk of the brunette contains more sugar than that of the blonde, in the proportion of 7 to 5.85. It is increased by a vegetable diet. (*Dumas and Bensch.*) Diseases—especially syphilis—do not appear to modify its amount, nor does either an abundant or an insufficient diet.

3. The *salts* are less than one-half as abundant in woman's milk as in that of the cow; the latter containing 5.5 to 8.5 in 1,000. The difference, however, more especially affects the insoluble salts belonging to the caseine, and which are diminished with its diminution. The principal salts are the chlorides of sodium and potassium, and phosphates of the alkalies, lime, and magnesia, besides the alkali combined with the caseine.

4. The *fat* (butter) of woman's milk is supposed to be richer in oleine than that of cow's milk. It is increased by fatty food. The whole amount of fat is much less than in cow's milk (the latter containing 45 in 1,000), and remains nearly the same through the entire period of lactation. The milk first drawn from the breasts is poorer in fat than that flowing afterwards. The fat also diminishes in diseases.

Albumen has been detected in milk in case of inflammation of the lacteal gland. But doubtless mere congestion may cause it to appear, a transudation being thus mixed with the normal secretion. *Urea* may occur in the milk in Bright's disease of the kidney. Iodide of potassium may also pass into the milk, but it has not been *proved* that other medicinal substances can.

The *quantity* of milk secreted by a healthy nursing-woman, from

both breasts, in twenty-four hours, averages about 2 pounds and 14 ounces, or 22 grains for every 1,000 grains of her weight. A cow secretes only 10.4 grains to 1,000, or 13 pounds and 4 ounces in all.[1] (*Lehmann.*)

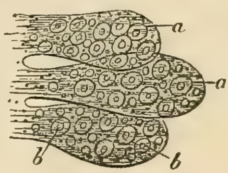
Origin.—Milk is secreted by the epithelial cells of the ultimate follicles or cœca of the lacteal glands. It is not to be, hence, inferred, however, that its constituents exist preformed in the blood; for true secretion (the urine alone, perhaps, excepted) always implies that the fluid secreted is formed in the cells *from* the elements in the plasma of the blood, and therefore contains elements not to be found in the latter. It has already been stated that the sugar is formed in the mammary gland (p. 72); and the assertion of Mialhe, that caseine exists in the blood, though probable, has not been fully confirmed (p. 88). The caseine of the milk is pretty certainly derived from the albumen in the blood.

The ducts and terminal follicles of the lacteal gland are shown by Figs. 114 and 115.

Fig. 114.

Milk-ducts terminating in clusters of follicles.

Fig. 115.



Terminal cœca (follicles) of lacteal gland, with their secreting cells (*a, a*); nuclei (*b, b*).

The epithelial cells lining the follicles (Fig. 115) may be seen to contain the milk-globules, and are therefore proved to be the real agents in this secretion. On bursting, they set the globules free in the follicles, which, communicating with the ducts (Fig. 114), pour the milk into the latter.

Uses.—Milk is the normal food of all the mammalia during the first period after birth. It therefore combines all the elements necessary for perfect nutrition and rapid growth. A discussion of all its important physiological relations would, however, be out of place here. The caseine is its *nutritive* element (p. 89).

If, however, milk is the proper nourishment for the infant, while

[1] More than double the quantity here mentioned by Lehmann is very generally secreted by the cow, in this country.

growth and development are rapid, it cannot be so for the aged. Seizures simulating apoplexy are sometimes produced by milk in aged persons not accustomed to its use.

Woman's milk usually becomes suddenly deficient in caseine at the end of a year after parturition. This may be accepted as an indication that lactation should not, as a general rule, be prolonged beyond this period. Up to this time it becomes more and more nutritious, in proportion to the increased size and strength of the infant.

It frequently becomes necessary to substitute the milk of one of the lower animals for that of woman, and the following facts are of interest on this subject:—

1. *Cow's* milk contains a small amount more of solid constituents than woman's milk, in the proportion (average) of 140 to 120 in 1,000 of milk. It contains more caseine (41.6 : 34.3), more fat (45 : 25.3), and far more salts (7 : 2.3). On the other hand, it contains less sugar (38.5 : 48.2).

Consequently, if from 1,000 parts of cow's milk nearly one-half ($\frac{4}{9}$) of the cream is first removed, and then 186 parts of water and 10 parts of sugar be added, the result will, in composition, very nearly resemble woman's milk, except that the salts will still be too abundant. The following formula will, therefore, answer, for practical purposes, as nourishment for an infant:—

℞.—Cow's milk . . 16 ounces (1 pint).
(Remove one-half the cream.)
Water . . . 3 ounces (6 tablespoonfuls).
Sugar . . . $\frac{1}{6}$ ounce (a large teaspoonful).

2. *Goat's* milk is sometimes substituted for that of woman. It contains 132 to 145 of solid constituents, of which 40.2 to 60.3 are caseine, 33.2 to 42.5 are fat, and from 40 to 53 are sugar, in 1,000 parts.

3. The milk of the *ass* has less (only 91.6 to 95.3) of solid constituents, there being only 16 to 19 of caseine, from 12.1 to 12.9 of butter, and 62.9 to 68 of sugar. It is the richest of all in sugar, but poor in caseine and butter.

4. *Mare's* milk contains 162 in 1,000 of solid residue, but little caseine (17), a large amount of fat (69.5), and the most sugar of all (87.5).

5. *Sheep's* milk contains 143.8 of solid constituents, 40.2 being caseine, 42 fat, 50 sugar, and 6.8 salts.

A formula may be easily deduced from the preceding data, if it be desirable to sustain the human infant on the milk of either of the four animals last mentioned.

The only *carnivorous* animal whose milk has been analyzed is the *bitch.* Her milk has an acid reaction (when she is fed on animal food), and contains 274.6 to 224.8 in 1,000 of solid constituents. Of these, 80 to 110 are caseine, from 68.4 to 109.5 are butter, while the quantity of sugar of milk is very small. The last and the butter are increased by mixed food. The great amount of caseine and of fat deserves especial notice, in a physiological point of view.

II. Semen.

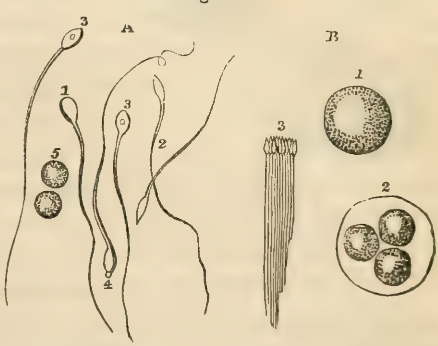
Semen, as usually observed, is mixed with the prostatic fluid and that secreted by Cowper's glands and the vesiculæ seminales. It can be obtained in its pure state only from the vasa deferentia and the testes of animals in heat. When mixed as just stated, it is a mucous, viscid, colorless fluid, considerably heavier than water, and of a neutral or slightly alkaline reaction.

1. The *liquor* seminis, a great part of which is derived from Cowper's glands, the prostate, and the vesiculæ seminales, gelatinizes after emission; the gelatinizing substance (spermatine) resembling mucus more than fibrine.

The salts most abundant in it are the phosphates of lime and magnesia. The fat (p. 78) exists principally in the cells hereafter to be described. Vauquelin found 10 per cent. of solid constituents in the semen—viz., 6 per cent. of organic matter, 3 of earthy phosphates, and 1 of soda.

2. The peculiar histological element of the semen, the *spermatozoids*[1] (spermatic filaments), are the most singular developments in the organism. They occur in the semen of all animals, and are analogous in form in all, though distinguishable in each species, as a general rule; consisting of a round, oval, or pyriform body, to which a long filament or tail, gradually tapering to a point, is attached.

Fig. 116.



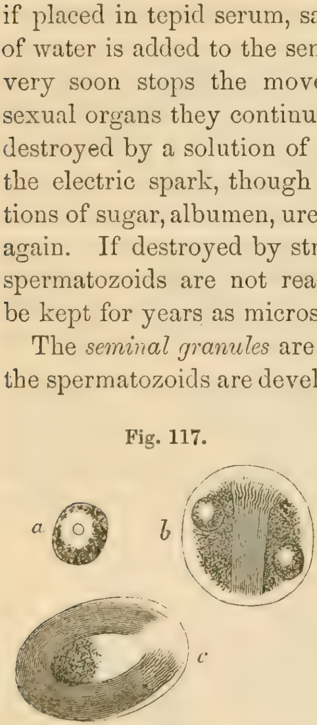
Human spermatozoids. A. From the vas deferens: 1 to 4, their variety of character; 5, seminal granules. B. From testis: 1, large cell; 2, same, containing three granular bodies, from which the spermatozoids are developed; 3, a bundle of spermatozoids still grouped together.

[1] From σπέρμα, semen, ζῶον, animal, and εἶδος, resemblance.

(Fig. 116.) In the human spermatozoid the body is from $\frac{1}{6666}$ to $\frac{1}{5000}$ of an inch long, and from $\frac{1}{17000}$ to $\frac{1}{9000}$ of an inch in width, and the filament is from $\frac{1}{666}$ to $\frac{1}{500}$ of an inch long. They were formerly regarded as infusorial animalculæ, on account of their active motions, the tail striking rapidly from side to side, and propelling the body in a zigzag direction. This motion may be retained a long time if the semen is prevented from evaporation, or if placed in tepid serum, saliva, or mucus. If double its quantity of water is added to the semen, the power of motion is lost. Urine very soon stops the movements. In the interior of the female sexual organs they continue longer than elsewhere. Motion is also destroyed by a solution of opium, by alcohol, by strychnia, and by the electric spark, though not by galvanism. Concentrated solutions of sugar, albumen, urea, and various salts re-excite the motions again. If destroyed by strychnia, the tail remains extended. The spermatozoids are not readily destroyed by putrefaction, and may be kept for years as microscopical objects, in the dried state.

The *seminal granules* are also peculiar to semen, and within them the spermatozoids are developed. Hence they are also called *spermatophori*. These are finely-granular, pale, sharply-outlined corpuscles, from $\frac{1}{7500}$ to $\frac{1}{1200}$ of an inch in diameter. Fig. 117 shows the development within them of the spermatozoids.

Fig. 117.



Phases of development of spermatozoids. *a*. Original nucleated cells. *b*. The same enlarged, showing spermatozoids. *c*. The latter nearly perfect, but still inclosed within the cell.

We also find in semen scattered epithelial cells, cytoid (mucus) corpuscles, and minute fat-granules; neither of which presents any peculiarity.

The *recognition* of semen is often a matter of great medico-legal importance. A microscopic examination will at once detect the spermatozoids, their form is so characteristic. Urine containing semen very readily becomes alkaline. Seminal spots (as on linen) have been shown by Schmidt to differ from all others. The glistening surface of the spot will decide on which side of the linen it is, and here only can spermatozoids be found. He found that seminal spots became of a pale yellow color when kept near the fire for an hour or two, while the form of the spermatozoids is not

changed. Other substances, treated in this way, are colored green (as vaginal mucus), or are not changed in color.

Origin and Uses.—The spermatozoids are developed within the spermatophori, as already stated, and are the part of the semen indispensable to impregnation. The spermatophori are probably developed from the spermatine, as cytoid corpuscles are in plasma, as described on page 146. Their relation to the seminiferous tubes of the testis will be explained in the chapter on "The Sexual Organs."

III. Glandular Secretions discharged into the Alimentary Canal.

1. *Saliva.*

Saliva, as obtained from the oral cavity, is a mixture of the secretions from the three salivary glands with the mucus of the mouth. It is a cloudy, viscid, slightly opalescent fluid, without taste or smell, and of alkaline reaction. Its specific gravity varies from 1004 to 1006, and its solid constituents from 0.35 to 1 per cent.

The only histological elements in saliva are epithelial cells and cytoid (mucus) corpuscles; neither of which are, of course, peculiar to it.

The pure saliva varies with the gland secreting it, whether the parotid, submaxillary, or sublingual.

The secretion of the *parotid* gland has a specific gravity of 1006 to 1008.8, is clear as water, and without color, taste, or odor; and contains 1.4 to 1.6 per cent. of solid constituents. It contains much chloride of sodium and of potassium.

The secretion of the *submaxillary* gland resembles the preceding, but is more viscid, less strongly alkaline, and has a less specific gravity (1004) and less solid residue (0.855 per cent.); and that of the *sublingual* gland is the most viscid of the three. All of these secretions contain a peculiar organic substance—*salivine*, or ptyaline (p. 83).

Recent experiments give 3 pounds and 6⅓ ounces (avoirdupois) as the average quantity of saliva secreted by adults in twenty-four hours. (*Lehmann.*) The quantity is increased by the mastication of dry and hard alimentary substances, and by movements of the jaw, whether in chewing, speaking, or singing. Acid, aromatic, and pungent substances have the same effect.

Iodide of potassium is always found in saliva after the use of iodine, and mercury enters it in case of mercurial salivation. It is also *acid* in certain abnormal states, and usually so during fasting.

Origin.—Saliva is secreted by the epithelial cells of the minute subdivisions of the ducts in the three salivary glands.

Uses.—The *mechanical* functions of saliva are fivefold:—

1. It conduces to phonation and articulation, by securing a proper degree of moisture of the tongue and oral cavity.
2. It aids the sense of taste.
3. It cleanses the mucous membrane of the oral cavity.
4. To a certain extent it quenches, or rather prevents, thirst.
5. It aids in mastication and deglutition, and carries air into the stomach, the latter being inclosed in the form of bubbles during mastication. Bernard has shown, however, that it is the parotid secretion which prevents thirst, while that of the sublingual is subservient to deglutition, and that of the submaxillary conduces to the perfection of taste.

An important *chemical* agency has also been attributed to saliva; the power of changing the starch of the food into sugar. Bernard has, however, proved that only mixed saliva has this effect, and only when in a state of *incipient decomposition.* In fact, the influence of saliva upon starch has been much overrated; the pancreatic and intestinal fluids being the principal agents for the conversion of the amylacea into sugar. It normally only *hydrates* the starch after it arrives in the stomach.

2. *Bile.*

Bile, as obtained from the gall-bladder, is a viscid fluid, capable of being drawn into threads; of a green or brown color, a bitter taste, and a peculiar odor (often resembling musk). Its specific gravity is about 1020, and it is usually alkaline, often neutral, and very rarely acid, even in disease. When it contains much mucus, it putrefies very readily; when nearly free from it, with difficulty, or not at all. It doubtless always contains some of this element, and to its presence the viscidity of the bile is due. *Pure* bile has not yet been analyzed.

The only *morphological* element in bile is the conoidal epithelial cell of the gall-bladder and biliary ducts.

Bile, as usually obtained for examination, contains, on the average, 14 per cent. (10.2 to 17.3) of solid constituents; 90 per cent. of these

being organic matters, and 10 per cent. mineral substances. It becomes more concentrated by a prolonged stay in the gall-bladder.

The *organic* matters in bile are—1. The bile-pigment (the brown and the green) already described (p. 101); 2. Cholesterine (see p. 75); and which, with fat and fat-acids, form 27 to 30 per cent. of the solid residue.

Among the *mineral* constituents of bile, the chloride of sodium preponderates. There are also found some phosphate and carbonate of soda, phosphate of lime and magnesia, and traces of iron and magnesium.

The *amount* of bile secreted in twenty-four hours is unknown. Bidder and Schmidt's experiments on the lower animals would lead to the conclusion that it is not less than 23 ounces[1] in the case of an adult man weighing 140 pounds. It is increased by animal food, in quantity, and at the same time in density.

Fat, taken in abundance, increases it also. On the other hand, it is considerably diminished by the *carbonate of soda*, and by febrile diseases. Calomel increases it; but only so far as the water is concerned—the solid constituents remaining the same.

The bile is constantly secreted; but increases about three hours after the reception of food, and so continues for some hours afterwards. After prolonged abstinence it is reduced to one-fourth the quantity of the secretion afforded in the twenty-fourth hour after the last meal. If an animal is fed exclusively on fat, no more bile is secreted than during fasting. The gall-bladder empties itself in two and a half to three hours after taking food.

Origin.—There can be no doubt that the bile is *formed* in the liver.[2] Not one of its constituents exists preformed in the blood of the portal vein; and icterus does not occur in any disease which attacks the parenchyma of the liver, and thus entirely suppresses the secretion of bile. The epithelial cells lining the terminal subdivisions of the hepatic ducts are the immediate agents of the biliary secretion. Fig. 118 shows Kölliker's idea of the relations of these cells to the "parenchymal cells" of the liver itself; the ducts directly *abutting* upon the latter, as he believes; and Fig. 119, the secreting cells when isolated. The actual structure is,

[1] Todd and Bowman estimate the quantity at 54 ounces, containing 2 ounces of solid constituents (pt. iv. p. 480).

[2] Except, perhaps, the pigment. (See p. 101.)

however, shown by Fig. 370, and explained in the section upon the liver.

Fig. 118.

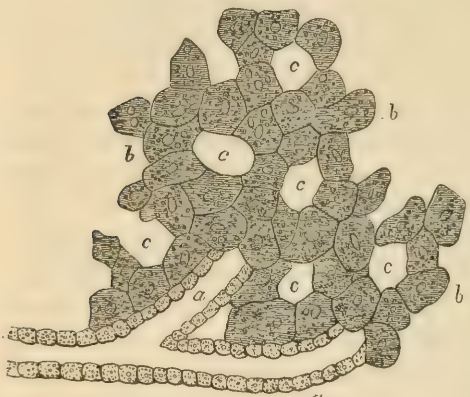
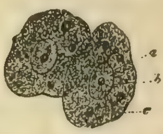


Diagram of the arrangement of the cellular parenchyma (*b b*) of the human liver, with reference to the radicals of the interlobular ducts (*a a*), and the vascular spaces (*c c*).

Fig. 119.



Isolated cells of the liver. *a.* Nucleus. *b.* Nucleolus. *c.* Oil-particles.

The *sugar* formed by the liver is not an element of the bile (p. 70). It is found in the "parenchyma" of the liver, and is greatly increased in diabetes.

Function.—Several distinct functions have been ascribed to the bile:—

1. It neutralizes the acids of the gastric fluid, when the contents of the stomach enter the duodenum. The latter always react acid; but it is to the quickly decomposing acids of the bile that the acidity is due. It also precipitates the substances dissolved by the gastric fluid, and hardens those softened by it. (*Bernard.*)

2. It prevents the putrefactive decomposition of the contents of the intestine; holding them, as it were, in *statu quo* till the pancreatic fluid exerts its peculiar action upon them.

3. The power attributed to bile in dissolving fat has been overrated; though it cannot be wholly denied. It is a well known fact that bile removes greasy stains; and it has been shown that fat passes much more easily through membranes saturated with bile than through those moistened with water. It is also found that $2\frac{1}{2}$ times less fat is absorbed from the intestine when the access of bile is prevented. The influence of bile, therefore, in aid of the absorption of fat is undoubted.

4. Finally, bile aids in securing a regularity of defecation, from its stimulating effects upon the muscular coat of the alimentary canal.

Pathological States of the Bile.

Albumen is found in the bile in the embryonic state, sometimes in fatty liver, in Bright's disease, and in cases of abscess of

the liver. The albumen is, in these last cases, probably due to transudation.

Urea occurs in the bile in uræmia, and therefore principally in cholera and Bright's disease.

The solid constituents are usually increased in the bile in cases of cardiac affections and abdominal diseases which produce congestion in the large veins; and in cholera, in which disease all the fluids become more dense from the loss of water.

On the other hand, the bile is more *watery* after violent inflammations, in dropsical affections, typhus, tuberculosis, and diabetes. In these conditions the amount of water in the bile seems always to be in a certain proportion to that in the blood.

Biliary *concretions* (chololithi) are of three kinds: 1. Of cholesterine, inclosing a nucleus of pigment; 2. Of the chalky pigment alone; 3. Of pigment with lime; of a dark green or black color, and almost free from cholesterine.

The regurgitation of bile into the stomach at once arrests the action of the gastric juice (p. 200).

3. *The Pancreatic Fluid.*

This secretion is colorless, clear, slightly viscid, tasteless, and odorless, and presents a tolerably strong alkaline reaction. It coagulates on being heated. Its specific gravity is variable; the concentration standing in inverse ratio to the quantity of secretion afforded in a given time.

The pancreatic fluid transforms starch into sugar in a few minutes, and decomposes the neutral fats into glycerine and the corresponding fat-acids.

About seventy-eight per cent. of the solid residue of this fluid is the organic substance peculiar to it—*pancreatine* (p. 83).

The *mineral* constituents of this fluid are, principally, chloride of sodium, phosphates of the alkalies and earths, sulphates of the alkalies, and carbonate of lime.

The *quantity* of the pancreatic fluid is not accurately known. Experiments indicate that it varies not far from $4\frac{2}{3}$ ounces in twenty-four hours in an adult man. (*Bidder and Schmidt.*) It is independent of the volume of the pancreas, and attains its height during the period of digestion. Ingestion of solid food, and also especially of drinks, augments it.

Origin.—The pancreatic fluid is secreted by the epithelial cells of the ultimate subdivision of the duct of (*Wirsung*), the pancreas.

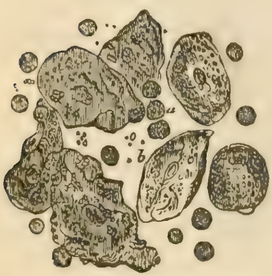
Function.—The pancreatic fluid changes starch into glucose, the albuminous elements of the food into albuminose, and the fatty into

an emulsion (*Bernard*); the last being absorbed partly by the lacteals and partly by the bloodvessels of the villi, and the first two by these vessels alone. It cannot, however, be the main agent in changing the fatty elements below the jejunum; since it is changed or reabsorbed before it reaches the middle of the small intestine. The intestinal fluid supplies its place in this respect, through the remaining portions of the alimentary canal (p. 201).

IV. Urine.

The urine is of a lighter or deeper amber color, and has a bitter saline taste; being, while still of the temperature of the body, perfectly clear and transparent, and of a peculiar faintly aromatic odor, and acid reaction. Its specific gravity never, in the normal state, rises above 1030 (*Lehmann*), and averages not more than 1020.

Fig. 120.



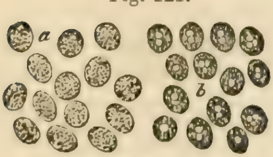
Mucus-corpuscles and epithelial cells in urine.

The only *morphological* elements normally found in urine are epithelial cells, and more or less cytoid (mucus) corpuscles (Fig. 120); these being accidentally present, as they are in the other glandular secretions, and presenting nothing peculiar.

But in *pathological* conditions, a variety of histological elements may be found. Of these, the spermatozoids, pus- (cytoid) corpuscles, blood-corpuscles, and fibrinous casts of the tubuli uriniferi, are the most common; to which may be added cells and fibrinous casts containing fat-globules, as occurring in Bright's disease; and the large and small organic globules.

1. *Spermatozoids* (Fig. 116) are found most abundantly in the urine after pollutions and sexual intercourse, and are not to be referred to a pathological state except in some cases of spermatorrhœa.

Fig. 121.



Pus-corpuscles in urine.

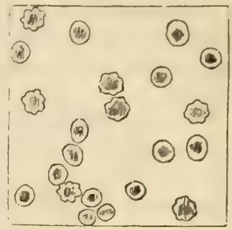
2. *Pus* occurs in urine (Fig. 121) in cases of inflammation of the bladder; but the pus-corpuscle not being distinguishable histologically from the mucus corpuscles (p. 146), needs not a distinct notice here. Cytoid-corpuscles abound in the urine in case also of inflammation of the kidney and the prostate; and in vesical catarrh, so called.

3. *Blood-corpuscles* appear in inflammation of the kidney, &c.; in consequence of hemorrhage from any part of the urinary passages.

Their form is changed by the action of the fluid in which they are found, they most frequently resembling transparent rings. (Fig. 122.)

4. The *casts* of the tubuli uriniferi are bottle-shaped or cylindrical in form, and resemble fine hairs. They are from less than $\frac{1}{100}$ to $\frac{1}{50}$ inch long, and $\frac{1}{1000}$ inch in diameter; and present three varieties: 1. Those consisting of the epithelial coat alone of the uriniferous tubes. These are observed in the commencement of Bright's disease, and in the desquamative stage of erysipelas and scarlatina. 2. Those consisting of recent exudation; generally granular, and containing more or less blood and pus-corpuscles. 3. Those consisting of pure coagulated fibrin; resembling hyaline tubes, and often hard to recognize on account of their transparency.[1]

Fig. 122.



Colored blood-corpuscles in urine.

5. *Fibrinous casts and cells*, containing fat-globules, are found in Bright's disease. Figs. 123, 124, and 379 represent these casts and cells.

Fig. 123.

Fibrinous cast of uriniferous tube.

Fig. 124.

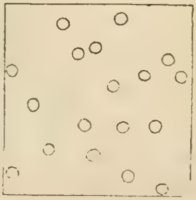
Fibrinous cast containing epithelium and fat-globules. *a.* Cells containing fat drops. *b.* A fibrinous cast.

6. The *large organic globules* (Fig. 125), are not unfrequently met with in the urine of pregnant women. They appear to be merely

Fig. 125.

Large organic globules (400 diameters).

Fig. 126.



Small organic globules.

[1] Dr. J. H. Bennet adds, the "waxy casts"—the detached basement-membrane alone of the tubes.

a larger kind of cytoid corpuscle than those of mucus or pus. They are, moreover, not attended by the viscid and the albuminous fluid which respectively characterize mucus and pus. (*J. E. Bowman.*)

The *small organic* globules (Fig. 126) are far more rarely found. They are spherical, smooth externally, and not granular within; are unaffected by acetic acid, and are much smaller than the preceding.

To these histological elements may be added a thread-like *fungus* (confervoid), called the torula. (Fig. 127.) These threads are made up of cells $\frac{1}{3960}$ to $\frac{1}{3360}$ of an inch in diameter. It occurs in decomposed urine, whether, as in vesical catarrh, decomposition com-

Fig. 127.

The torula in urine; crystals of uric acid and two epithelial cells.

Fig. 128.

Fungoid growths in the urine.

mences in the bladder, or after its emission. Another kind of fungoid vegetation occurring in urine is seen in Fig. 128, in connection with crystals of oxalate of lime.

Vibriones and *monads* also appear in decomposed urine; and the

Fig. 129.

Sarcina ventriculi.

sarcina ventriculi of Goodsir has frequently been found in it. (Fig. 129.)

In *chemical composition* 1000 parts of urine consist of 933 to 972 parts of water, holding 67 to 28 parts of solid matters in solution. The following analyses by Lehmann and Becquerel, present the proportions of each element:—

	Lehmann.		Becquerel.
Water	937.682		971.935
(Solid constituents 62.318)			(28.066)
Urea	31.450		12.102
Uric acid	1.021		0.398
Lactic acid	1.496	Other organic matters	8.647
Extractive matters	10.680		
Lactates	1.897		
Chlorides of sodium and ammonium	3.646	Fixed salts 6,919, containing— Chlorine	0.502
Alkaline sulphates	7.314	Sulphuric acid	0.855
Phosphate of soda	3.765	Phosphoric acid	0.317
Phosphates of lime and magnesia	1.132	Potash	1.300
Mucus	0.112	Soda, lime, and magnesia	3.944

It will be noticed that Lehmann found nearly twice the amount of solids obtained by Becquerel, and about $2\frac{1}{2}$ times as much urea and uric acid. Berzelius and Marchand agree in all these respects very nearly with the former, and Simon and Dr. Miller with the latter. Of course the composition of the urine varies with its specific gravity, and to this fact the disparity is doubtless due. Dr. Christison constructed a table showing the amount of solid constituents in urine of different specific gravities, which proves that the former increase very rapidly with slight increments of the latter. *E. g.* with a specific gravity of 1012, the solids are 27.96 in 1,000; while, if the former be increased to 1030, the latter are 69.90. If we look at the *urea* alone, we also find a rapid augmentation as the specific gravity increases. If the specific gravity is 1013.5, only 15 parts in 1,000 are urea; while, if the former be 1027, there will be 37.5 of urea—or just $2\frac{1}{2}$ times as much. (*Lehmann.*) To reconcile the analyses of Lehmann and Becquerel, we have therefore only to suppose that, while the specific weight in the latter was actually 1017.01, in the former it must have been at least 1025. But the results obtained by Becquerel are the more valuable

in practice, since the specific gravity averages not more than 1020, and is generally rather less than this, according to most writers.

Of all the constituents in solution in the urine, *urea* is the most important. Its proportional as well as its absolute amount varies extremely, the kind of food having a great influence in this respect (p. 69). An increased secretion of water is also accompanied by an increased amount of urea, in the twenty-four hours. *E. g.* if 1,000 grains of urine be secreted in twenty-four hours, 33 grains are urea; if 2,000 grains, about 42 grains of urea; and if 3,000 grains of urine, about 50 of urea. Of course the specific gravity will be lowest in the last case, so that the amount of urea in *one thousand parts of urine* will be least of all. It has been seen that the urea is derived directly from the nitrogenized elements of the food and of the decomposed tissues (p. 69).

Of *uric acid*, from 7.7 to 13.9 grains are excreted in the urine, by an adult, in twenty-four hours. Its amount depends less on the kind of food taken than on the internal conditions of the organism (p. 64).

Creatine and *creatinine* (pp. 67, 68) are normal constituents of the urine, but their amount has not been determined.

Formic acid is sometimes found in healthy urine, in very small quantities. *Hippuric acid* is hardly more abundant than the uric.

Lactic acid is not found in normal urine, but at once occurs in those states of the organism in which the process of oxidation is interfered with (pp. 60, 66).

The *chlorides* of sodium and potassium are very abundant in urine. An adult secretes about 162 grains of chlorine in twenty-four hours. They greatly diminish, or even entirely disappear, in diseases accompanied by copious exudations—as in acute dropsy, acute Bright's disease, acute tuberculosis, in violent diarrhœas, cholera, typhus, and pneumonitis.

The *sulphates* are found in variable quantities. An adult averages 31.4 grains of sulphuric acid in twenty-four hours. They are increased only by violent bodily exercise (as in convulsions and delirium tremens), and in high mental excitement.

The *acid phosphate of soda* (p. 57) is the principal source of the acid reaction of the urine. The phosphates of lime and magnesia are also found in considerable amount, and in the proportion, on an average, of 15 to 7. An adult discharges, on an average, 49.4 to 80.2 grains of phosphoric acid in twenty-four hours, and 15.4 grains

of earthy phosphates. The phosphates increase after taking nitrogenized food, and in acute affections of the nervous substance—*e. g.* in encephalitis (p. 49).

It sometimes occurs, in the last months of pregnancy, that no lime at all is secreted in the urine; there being little or none in the blood also, as will be shown (Chap. VII).

Traces of *iron* and silicic acid are usually found in urine; and *gases* are also dissolved in it, especially carbonic acid and a little nitrogen.

Some substances—alimentary or medicinal—pass *unaltered* into the urine. These are such as are easily soluble in water, and do not form insoluble compounds with the constituents of the body; and which are, moreover, not readily oxidizable or decomposable. Thus the nitrates, carbonates, chlorates, borates, and silicates of the alkalies, and the chlorides, bromides, and iodides of potassium and sodium, pass unaltered into the urine; while sulphuret of potassium is oxidized, and appears in the urine as sulphate of potassa. All the salts of the metals pass into the urine unchanged, only when taken in large quantities; since they form insoluble compounds with animal matters, especially with albumen. Mannite, quinine, &c., are fully oxidized into carbonic acid and water. Most of the organic acids, as well as sulphocyanide and ferrocyanide of potassium, reappear in the urine unchanged. Tannic acid is, however, converted into gallic, benzoic and cinnamic into hippuric, uric acid into urea, and oxalic acid into carbonic acid and water. The neutral salts of the alkalies, with the vegetable acids, reappear in the urine as carbonates; and hence the urine speedily becomes alkaline after their reception. Urea passes unchanged into the urine. Coloring or odoriferous matters generally pass unchanged or slightly modified. The following, however, do *not* reappear, viz: camphor, resin, inflammable oil, musk, alcohol, ether, cochineal, litmus, chlorophyl, and the coloring principle of alkanet.

The rapidity with which different substances appear in the urine varies much. Iodide of potassium often appears after four to ten minutes.

The following *abnormal* constituents may appear in the urine in pathological conditions, viz: albumen, fibrine, caseine(?), fat, sugar, abnormal pigments, biliary acids, bile-pigment, xanthine, cystine, carbonate of ammonia, sulphuretted hydrogen, butyric acid, and ammoniacal salts.

Sugar is, however, normally present in the urine during pregnancy, and of nursing women; always in the latter, and in one-half the cases of the former. Its amount varies from 1 to 12 grains in 1,000 of urine; it being more abundant as the milk is more abundant and rich. (*M. Blot.*)

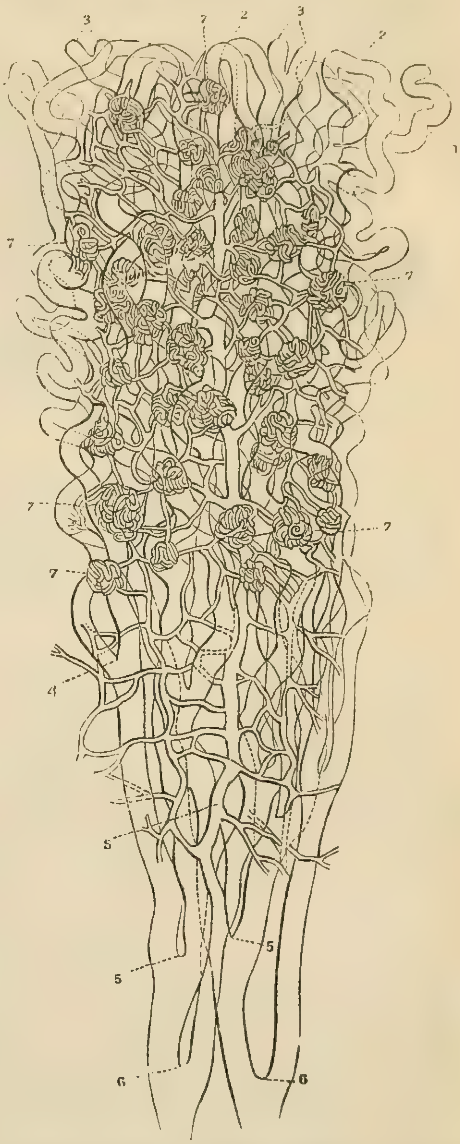
Albumen may appear in the urine in any case in which there is congestion of the kidney, or a too watery condition of the blood; its presence being due, doubtless, to a mere transudation, and not to a modified action of the secreting cells. Hence albuminuria is by no means peculiar to Bright's disease, but occurs also in the course of fevers, in renal catarrh, in cases of disease of the heart or lungs, or tumors of the abdomen, and frequently in dropsy. *Fat* appears in the urine after taking fatty food, though rarely. Isolated fat-globules are sometimes seen in cases of rapid emaciation; also, either free or in the tubular casts, in Bright's disease. *Ammonia salts* are found in the acid, and especially in the alkaline fermentation of the urine. In acid pathological urine the occurrence of ammonia is not unusual—as in typhus, measles, and scarlatina. Ammonia is almost always contained in alkaline urine; for the alkaline reaction depends either primarily on ammonia formed by the decomposition of urea (especially in vesical catarrh), or upon carbonates of the alkalies, which soon decompose the urea.

The *quantity* of urine secreted in twenty-four hours varies extremely, the two most important factors bearing on it being the mechanical conditions for the passage of urine through the kidneys, and the condition of the blood. (*Lehmann.*) An adult male excretes from 17¾ ounces to 112½ ounces in twenty-four hours; averaging between 38½ ounces and 48¼ ounces. The adult averages 40.13 grains to 1,000 grains of his weight; a child, 72.5 grains. The different proportions of water account in great part for the variations above mentioned in the quantity of urine; but the solid constituents are also liable to considerable variation, an adult discharging from 1¼ ounces to 2⅝ ounces in twenty-four hours. They are increased by exercise, and diminished by sedentary habits. Moreover, if the blood is poor in albumen and abundant in salts (as in Bright's disease), the solid constituents are diminished. The *mineral* constituents also vary greatly; between 108 and 355 grains in twenty-four hours—averaging 231.5 grains, or nearly half an ounce. The urine of women is richer in water and poorer in salts than that of men; and especially during pregnancy. Hence the formation, in the latter condition, of the pellicle improperly called *kiesteine*, in the manner already explained (p. 89).

Origin.—Urine is directly eliminated from the blood by the epi-

thelial cells of the uriniferous tubes. A great part of the water, however, is doubtless obtained by mere *transudation* into the uriniferous tubes from the vessels which form the Malpighian tufts or bodies. Hence increased pressure of blood in the finer renal vessels causes increased separation of water and of the solids, especially the salts. If, on the other hand, the arterial and capillary tension is diminished, the secretion is also diminished. It, however, by no means follows, as Lehmann implies, that the secretion of urine is a mere physical phenomenon, dependent upon the fact that the blood undergoes compression while in the vessels of the Malpighian tufts. The more characteristic elements of the urine are separated by a vital action of the epithelial cells, and hence their amount in twenty-four hours is more nearly constant in health; while a great part of the water, and of the salts probably, when in excess in the blood, are separated from the latter by trans-

Fig. 130.



Structure of the kidney. 1. Cœcal extremity of a tubulus uriniferus. 2, 2. Recurrent loops of tubuli. 3, 3. Bifurcations of tubuli. 4, 5, 6. Tubuli converging towards the papilla. 7, 7, 7, 7. Corpora Malpighiana seen to consist of plexuses of blood-vessels, connected with a capillary network. 8. Arterial trunk.

udation merely. Fig. 130 shows the relations of the uriniferous tubes, arterial branches, and Malpighian tufts in a section of the kidney; and Fig. 131 shows two tufts, with their afferent and effe-

Fig. 131.

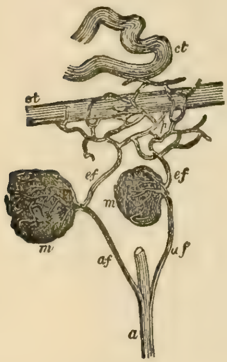


Fig. 132.

Fig. 131. Relation of Malpighian tufts to the vessels. *a*. Branch of the renal artery. *af*. Afferent vessel. *m*, *m*. Malpighian tufts. *ef*, *ef*. Efferent vessels. *p*. Vascular plexus surrounding the tubes. *st*. Straight tube. *ct*. Convoluted tube. (Magnified about 30 diameters.)

Fig. 132. Uriniferous tube and its epithelial lining. A. Portion of a secreting tube from the cortical substance of the kidney. B. The epithelium or gland-cells, more highly magnified (700 times). C. Portion of a tube from the medullary substance of the kidney. At one part the basement membrane has no epithelium lining it.

rent arteries. Fig. 132 shows a uriniferous tube with its epithelial lining, and, at B, a few cells, derived from its interior, of the scaly epithelium by which the true urine is secreted.

Uses.—Urine is merely an excretion, *i.e.* it consists essentially either of effete elements resulting from the disassimilation of the tissues, or of others existing in the blood in excess—the incessant removal of which is essential to the health of the organism.

Urinary Deposits.

Though normal urine is perfectly clear and transparent when first emitted from the bladder, *solid* matters soon appear in it, forming a pellicle on its surface, or a sediment; and which are called *urinary deposits.* These are quite numerous, as found in various normal and abnormal conditions, and may be divided into two classes: 1, histological elements; 2, crystalline substances of mineral and organic origin.

I. The *histological elements* have been specified at the commencement of this section, these being of course all suspended in the urine while it is still in the bladder, viz:—

1. Scaly epithelium. (Fig. 132.)
2. Mucus and pus (cytoid), corpuscles. (Figs. 120 and 121.)
3. Blood-corpuscles. (Fig. 123.)
4. Albumen. Heat and nitric acid solidify it, and make it apparent (p. 86).
5. Fibrinous casts (three forms), together with fat-globules. (Figs. 123, 124, and 379.)
6. Organic globules (two kinds). (Figs. 125 and 126.)
7. Spermatozoids. (Fig. 116.)
8. Fungi (two kinds). (Figs. 127, 128.)
9. Sarcina ventriculi. (Fig. 129.)

II. The *crystalline* (except carbonate of lime) deposits of *mineral* origin:—

1. Chloride of sodium. (Figs. 1 and 2.)
2. Triple phosphate. (Figs. 6 to 9.)
3. Carbonate of lime (usually amorphous). (Fig. 3.)

Those of *organic* origin, and their compounds with mineral substances, are:—

1. Urea. (Fig. 37.)
2. Uric acid (various forms). (Figs. 11 to 19.)
3. Urate of soda. (Fig. 22.)
4. Cystine. (Fig. 38.)
5. Hippuric acid. (Fig. 25.)
6. Oxalate of lime (various forms). (Figs. 26 to 31.)

Urinary Concretions. (*Vesical and Renal Calculi.*)

Calculi in the bladder and kidneys are formed by precipitation of the solids in solution in the urine, around a *nucleus*, so called. This is sometimes a foreign body introduced into the bladder from without; and sometimes a particle of mucus or other animal substance (and still oftener uric acid), formed within it. In either case, as soon as the nucleus is formed, the mineral constituents of the urine may be precipitated around it, and thus a calculus is concentrically formed. The composition of the calculus will, of course, depend upon the constituents precipitated; and very frequently it happens that the concentric layers are formed of different substances. Such are termed *alternating* calculi; and they alone demonstrate the incorrectness of the doctrine of diatheses—as the uric acid diathesis, the phosphatic diathesis, &c. (Fig. 34.)

Calculi found in the bladder may be first formed in the substance of the kidney. Calculi are also formed in the prostate gland (p. 54); but these are, of course, not concretions from the urine.

The following abstract shows the composition of 353 calculi in Guy's Hospital; and of 78 in the Museum of the Transylvania University; the last having been examined by Dr. Peter.[1]

[1] Bird on Urinary Deposits, pp. 321–23.

	Guy's Hosp.		Trans. Univ.
Nuclei of uric acid . . .	250		32
" urate of soda . .	18		26
" " lime . .	1		
" uric oxide . . .	1		
" cystine . . .	11		2
" oxalate of lime . .	47		7
" phosphates { lime 2, triple 1, mixed 19 }	22		7
" foreign substances .			4
Mixed calculi	3		78
The *bodies* were composed of—			
Uric acid (Figs. 20, 21) in . .	47		34
Urates of soda, &c. (Fig. 23.) .	186		2
Cystine	12		2
Oxalate of lime. (Figs. 32, 33.) .	26		16
Triple phosphate. (Fig. 10.) . .	14		4
Phosphate of lime	12	(mixed)	66
Fusible mixed phosphates . .	41		
Carbonate of line	1		
The *crust* was composed principally of—			
Uric acid in	40		34
Urate of soda	11	{ with phosphates }	2
Cystine	11		2
Oxalate of lime	11		9
Triple phosphates	14		2
Phosphates of lime	19	(mixed do.)	37
Fusible mixture of phosphates .	27		
Carbonate of lime	1		

The frequent occurrence of uric acid as a nucleus in the preceding calculi is remarkable (p. 63); and Lehmann states that a trace of uric acid, if nothing more, may always be detected in the nucleus of the concretion (Vol. II. p. 124). Scherer maintains that it is an acid fermentation of the mucus in the urine, which leads to the first precipitation of the uric acid, and therefore mucus must be first present and form a part of the nucleus. Mere irritation of the bladder may produce an abnormal mucus, and thus become the first step towards the foundation of the nucleus. An alkaline fermentation of the urine, on the other hand, leads to the deposition of the phosphates (as in paralysis of the bladder, &c.); and hence calculi may present the alternating layers (Fig. 34), already described.

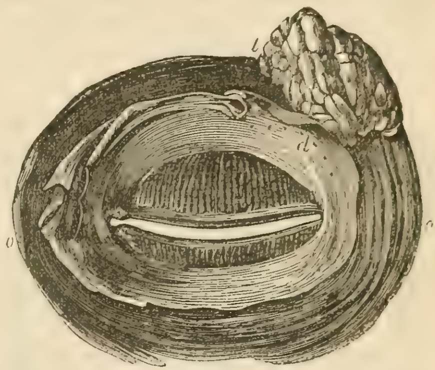
V. The Lachrymal Fluid.

The lachrymal fluid is a clear, transparent fluid, the principal elements of which are water, common salt, and an organic compound called by some chemists *lachrymine*. Any mucus-corpuscles or epithelial cells in it come from the mucous membrane of the eyelids.

Origin.—This fluid is secreted by the epithelial cells of the cœca of the lachrymal gland. (Fig. 133.)

Use.—The lachrymal fluid lubricates the eyeball, and thus diminishes friction between it and the eyelid. In case of copious weeping, much of the fluid is merely a transudation, mixed with the secretion of the lachrymal gland.

Fig. 133.



Conjunctival or inner surface of eyelid. *l.* Lachrymal gland. *d.* Orifices of its 7 ducts on the conjunctiva. The Meibomian glands are seen running towards the edges of the lids. *o, o.* Orbicularis muscle beyond the lids. (*Sœmmering.*)

CHAPTER IV.

THE CUTANEOUS SECRETIONS.

The secretions of the skin are two; the sebaceous secretion and the perspiratory.

I. The Sebaceous Secretion.

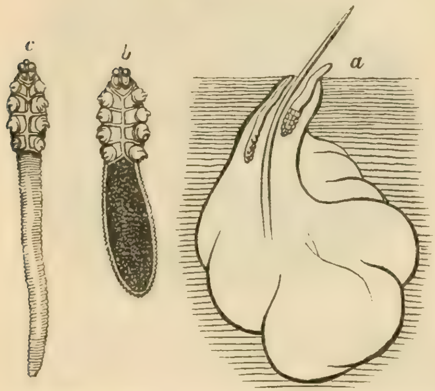
This is secreted by the sebaceous follicles (glands), situated in the substance of the corium of the skin. The Meibomian and the ceruminous glands also belong to this class.

The secretions of all these glands are by no means precisely identical. In all of them, epithelial cells may be found as a morphological element; the scaly cells of the skin often predominating

over the conoidal ones from the interior of the follicles. In the Meibomian secretion and the cerumen, peculiar oval, angular, or roundish cells are found, from $\frac{1}{2400}$ to $\frac{1}{1680}$ of an inch in diameter, containing a pale nucleus and nucleoli, with minute dark, sharply defined granules, and a few fat-globules.

When in a state of inflammation, the sebaceous follicles, like the mucous, produce (cytoid) pus corpuscles. Mere irritation may also give rise to them. They are best seen in cases of inflammation of the external auditory passage, and of the Meibomian glands, in balanitis, and in acne; there being, in these cases, also an *exudation* in which the cytoid corpuscles are developed. The parasite called *acarus folliculorum* is often found in the normal secretion of the sebaceous follicles. (Fig. 134.)

Fig. 134.



Entozoa from the sebaceous follicles. *a*. Two seen in their ordinary position in the orifice of one of the sebaceous follicles of the scalp. *b*. Short variety. *c*. Long variety.

The fluid portion of these secretions contains an albuminous substance not yet accurately recognized. But fat and lipoids constitute the principal part of them. It constitutes 47.5 per cent. of the vernix caseosa of the full grown fœtus (*Lehmann*), and 52.8 per cent. of the smegma of the human prepuce.[1] It has been ascertained that the liquor amnii contains most fat at the end of pregnancy; it being derived from the sebaceous follicles of the fœtus. In the vernix caseosa many hairs are always to be found; this tissue being intimately associated with the sebaceous follicles, as will be shown. The margarates and oleates of potash, soda, and ammonia are also elements of these secretions. Cholesterine is found in the smegma præputii, and a substance very similar to it, but not crystallizable, in vernix caseosa. Berzelius found a peculiar fatty substance in the cerumen.

The sebaceous follicles are always situated close, or very near, to

[1] Kölliker asserts that the smegma præputii is formed almost exclusively of the epithelial cells of the prepuce. (See Chapter X.)

the hair follicles, and often open into them; except that on the nymphæ and the glans penis, and on the inner surface of the prepuce, these follicles exist while hairs do not. (Fig. 135.) Vauquelin examined the fat of human hair, and found it oleaginous, colored, and containing sulphur.

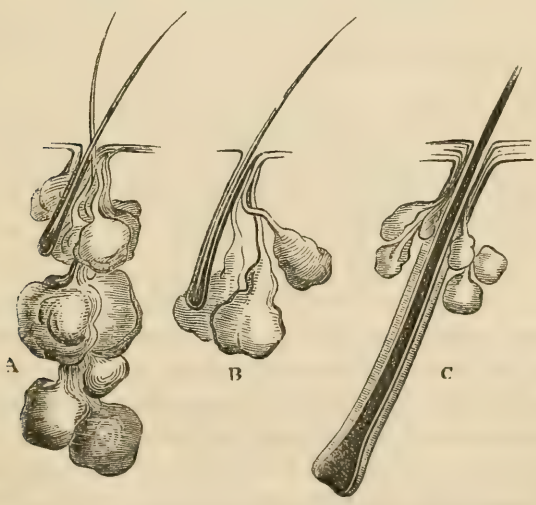
The *mineral* constituents of these secretions are, a little chloride of sodium and hydrochlorate of ammonia, with phosphate of ammonia and soda. Earthy phosphates are, however, more abundant: the vernix caseosa contains 6.5 per cent. and the smegma præputii 9.7 per cent.

Of *water*, the vernix caseosa contains from 66.98 to 77.87 per cent. In the sebaceous secretions after birth it must be constantly varying with the hygrometric and thermometric states of the surrounding air.

The *castoreum* used as an antispasmodic is merely the smegma from the preputial folds of the penis and the clitoris of the beaver. Canadian castor contains 5.8 per cent. of albuminous matter, 8.249 of fatty matters, and 41.34 of resinous constituents. (*Lehmann.*)

Origin.—The sebaceous secretions are secreted by the epithelial cells of the various forms of sebaceous glands. Figs. 135, 136, and

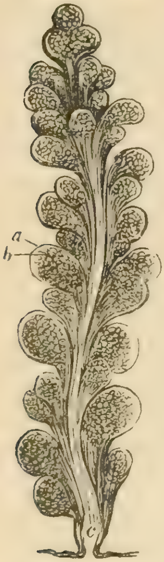
Fig. 135.



Sebaceous follicles of skin in their relation to the hairs.

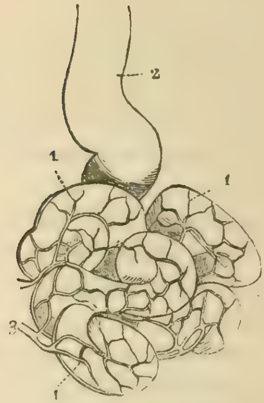
137 show the forms of the simple sebaceous follicles of the skin, and the Meibomian, and the ceruminous glands.

Fig. 136.



Meibomian gland. *a.* Basement membrane. *b.* Epithelial cells. *c.* Duct

Fig. 137.



Ceruminous gland, highly magnified. 1, 1. Tube forming the gland. 2. The excretory duct. 3. Vascular trunk and its ramifications.

Functions.—The sebaceous secretion diminishes the tendency to evaporation from the hair and the epidermis; and thus prevents the drying up of the deeper layers of the epidermis, and consequently of the corium.

The Meibomian fluid prevents the lachrymal fluid from flowing directly over the lids, from the conjunctiva; and the cerumen both secures a proper moisture of the auditory passage, and, by its nauseous odor, deters insects from entering it.

II. Perspiration.

True perspiration (sweat) is the fluid secreted by the perspiratory glands, which are situated beneath the skin, in the subcutaneous areolar tissue. They are delicate tubes, forming twisted coils at their commencement, from which they pass in a vertical direction through the corium of the skin, and in a spiral or cork-screw manner through the epidermis, to open upon the surface of the latter with a somewhat contracted mouth. Fig. 138 represents one of these glandular coils, with a part of its duct.

Sweat, as collected on the skin, is a colorless, very watery fluid,

with a saltish taste and more or less intense odor, and generally presenting a weak acid reaction. The sweat from the axillæ and the feet is, however, often found to be alkaline.

Fig. 138.

Sweat-gland and part of its duct. *a.* Venous radicle. *b.* Capillary plexus separated from the gland, and rising from arteries which also anastomose.

There are no morphological elements in sweat, except the scaly epithelial cells of the skin, which are accidentally present.

The *solid* constituents of sweat probably do not exceed 1.25 per cent.; Favre says .443 per cent. only. Of the solid constituents, chloride of sodium is the most abundant. The salts of ammonia are also present in it. Earthy phosphates and a little peroxide of iron are also present, but these are probably derived from the epithelial cells in the fluid.

The *fat* in the sweat may probably be, in great part, derived from the sebaceous follicles. But Krause has found that the sweat-glands also secrete fat, to some extent. Lehmann has proved that it contains butyric acid.

Sweat also contains the acetic and formic acids (*Schottin*), and the lactic (*Favre*), and a sulphurous matter (*Lehmann*). Urea is also a normal constituent. (*Favre.*) The thin bluish layer sometimes found on the bodies of persons who have died of cholera is a fine powder, composed, for the most part, of urea. Certain pigments sometimes occur in sweat, especially that of the bile in cases of icterus.

It has also been demonstrated that gases, especially carbonic acid and nitrogen, are given off in the liquid secretion of the sudoriparous glands, and these must not be overlooked in determining the functions of the skin. The carbonic acid predominates in case of a vegetable, and the nitrogen of an animal, diet. But less gas is, on the whole, given off when the perspiration is active, as after brisk exercise.

The *amount* of perspiration, in twenty-four hours, averages, in case of an adult man, not far from $25\frac{1}{2}$ ounces. (*Valentin.*) Krause calculated $25\frac{7}{16}$ ounces of water, $\frac{1}{4}$ ounce of organic and volatile

matters, and 38 grains of mineral substances. An adult man, in a vapor-bath, loses $\frac{3}{4}$ ounce of sweat in a minute. (*Lehmann.*)

About 412 cubic inches of carbonic acid gas are excreted from the skin of a full-grown man, in twenty-four hours, and a little less than one-half as much nitrogen. (*Abernethy.*)

Origin.—It has already been shown (p. 181) that a *transudation* is constantly occurring upon the surface of the skin, as a mere physical necessity; and doubtless very much of the fluid collectively called the sweat is produced in this way. The precise proportion of the true sweat, however, cannot be ascertained. Certainly, when the amount of perspiration is very suddenly augmented, as in a vapor-bath, it cannot be due to secretion wholly nor principally. But while secretion is probably thus increased, transudation is increased to a much greater proportional extent. In cases of colliquative sweats, and the cold sweat so common in *articulo mortis*, it is certainly not increased secretion, but mere transudation, which produces the excess of fluid.

Besides, it is probable that the gases escaping by the skin do so as a mere physical phenomenon, whether termed exhalation or otherwise.

So far, therefore, as the sweat is actually a *secretion*, it is doubtless secreted by the epithelial cells lining the tubes forming the perspiratory glands. But the portion elaborated by them constitutes the insensible rather than the sensible perspiration; and though it is highly probable that it contains all the substances mentioned as more characteristic of the sweat—as lactic, formic, and butyric acids—nothing positive is known on this point.

Uses.—One use of the sweat is, doubtless, to regulate the temperature of the animal body; an excess of perspiration, and its evaporation, being a cooling process.

But the main object of the perspiration is the elimination, it is said, of certain deleterious elements from the blood, it being one of the excretions. When we consider that more than $99\frac{1}{2}$ per cent. of the sweat is water (*Favre*), it hardly appears possible that this excreting power of the perspiratory glands has not been overrated. Yet all physicians are aware of the serious consequence resulting from a sudden "check of the perspiration," so called.

We doubt not that the perspiratory glands do eliminate excrementitious substances, and that their function is therefore important. But it is probable that the gases and volatile substances which

escape from the surface of the skin by mere exhalation and transudation are far more important as excretions than the actual elements of the perspiration. It is, therefore, probably because the action of the *skin* as an exhaling and transuding surface is suddenly checked, and not that of the *perspiratory glands* alone, that such serious consequences ensue from such sudden changes. It is far more because carbonic acid and nitrogen gases, and water also, cease to be given off, than because the perspiratory elements and the minute amounts of the acids of the sweat are still retained in the blood, that the mischief results. And it is not singular that the pulmonary surface, or that of the alimentary canal, or of the uriniferous tubes, should manifest a higher amount of power as a transuding surface when this physical process is suddenly checked on the skin; and that catarrhs, diarrhœas, or diuresis should result therefrom.

THIRD DIVISION.

THE TISSUES.

CLASSIFICATION OF THE TISSUES.

No classification of the tissues is possible which is not liable to some objections; but the following is proposed as the most simple, for the use of the student in histology. All tissues in which the microscope detects but one of the simple histological elements—whether cells, fibres, or membrane—are termed *simple* tissues; while if two or more elements are seen—as cells and fibres, or cells, fibres, and homogeneous substance—such are termed *compound* tissues. And the latter are termed binary or ternary, if constituted respectively of two or three elements.

In any classification, the distinction between mere tissues, and organs consisting in great part of those tissues, must be kept in mind. *E. g.* white fibrous tissue constitutes a great part of the ligaments and tendons; but mere white fibrous tissue is one thing, while a tendon or a ligament is another—the latter containing bloodvessels and areolar tissue, together with much of the tissue in question. So bone-tissue, or osseous tissue, is a *simple tissue;* but *a bone* is a *compound organ*, consisting of osseous tissue, vessels, nerves, lymphatics, &c.

We must also distinguish, in a classification, the tissue itself, from mere *cavities* which are found in it. Even though the latter may be peculiar to the tissue, and characteristic, they constitute no part of it whatever, and must exert no influence in deciding to what class the tissue belongs. These remarks apply more especially to osseous tissue, this being a simple tissue; though the cavities (lacunæ and pores) are more characteristic of bone, as seen under the microscope, than is even the solid substance itself.

Dental tissue is here associated with the osseous, though the enamel is more nearly allied, in its method of development, to epi-

thelium. The nails and the hair are classed with epithelium also: though the latter is often classed with teeth, and is, at the same time, a compound tissue.

Only the highest form of *muscular* tissue (the striated) is strictly compound; but there is an obvious advantage in arranging and describing the two forms in connection.

The fat-*cells* are a simple tissue; but adipose tissue is not so, and hence it is placed in the second class. It would be in accordance with analogy to term the fat-cells alone *fatty tissue*, and, when connected together with their vessels by areolar tissue, to apply the term *fat*—as we speak of osseous tissue and bone, of muscular tissue and muscle. In that case the term adipose tissue might be dropped, or *adipose tissue* and *adipose* might be used. For the present, however, it appears necessary to retain, as correlative terms, *fat-cells* and *adipose tissue.*

It will be hereafter seen that the mucous and serous membranes, and the skin, are composed of the same histological elements; and they are, therefore, here classed together. The vessels and the heart present no peculiar histological elements; but they are separately described on account of their great physiological importance. For a similar reason, distinct chapters are devoted to the alimentary canal, the urinary, the sexual, and the respiratory apparatus, the ductless glands, and the sensory organs.

Classification of the Tissues.

First Class.—SIMPLE TISSUES.

1. Epithelium. Hair and Nails.
2. Yellow Fibrous (Elastic) Tissue.
3. White Fibrous (Collagenous) Tissue.
4. Osseous Tissue, including Teeth.

Second Class.—COMPOUND TISSUES.

1. Areolar Tissue.
2. Adipose Tissue.
3. Cartilage and Fibro-Cartilage.
4. Contractile or Muscular Tissue (two forms).
5. Nervous Tissue—Vesicular and Fibrous.
6. The Membranes $\begin{cases} \text{Cutaneous (Skin.)} \\ \text{Mucous.} \\ \text{Serous.} \end{cases}$
7. The Vessels.
8. Alimentary Canal and Appendages.
9. Urinary Apparatus.

10. Sexual Organs.
11. Respiratory Organs.
12. Ductless Glands { The Spleen. / The Thyroid Body. / The Thymus Body. / The Supra-Renal Capsules. }
13. The Organs of the Senses.

In order, however, to avoid repetitions as far as possible, and to proceed at the same time in the most intelligible manner, the first seven tissues will be described in the following order; after which muscular tissue and the rest will follow in the order already given.

1. Epithelium and its modifications.
2. Yellow fibrous tissue.
3. White fibrous tissue.
4. Areolar tissue.
5. Adipose tissue.
6. Cartilage and Fibro-Cartilage.
7. Osseous tissue and the Bones;
   Dental tissues, and the Teeth.
8. Contractile or Muscular tissue, &c. &c.

CHAPTER I.

EPITHELIUM—NAILS AND HAIR.

THE epidermis and the nails have been by some authors termed the *horny* tissues; since, like the claws, horns, and hoofs of the lower animals, and whalebone, so called, and tortoise-shell—they contain the immediate principle called Keratine (p. 100). Both these, however, and the epithelia of mucous and serous membranes, are histologically so similar, that they will be described under the head of epithelium; and the hair, next in order, as being an epithelial appendage.

All epithelial developments are destined to fall off, and thus be lost to the organism, after accomplishing their proper functions; and they all consist of cells of various forms which have, in a mea-

sure, dried up if externally situated, and which are agglutinated to each other by an intercellular substance difficult of detection. Besides this last "problematical substance" (*Lehmann*), there are three distinct elements of the cells: 1, the substance of the cell-*membranes*, which constitutes the principal portion of all these tissues: and, which is almost insoluble in alkalies; 2, the cell-*contents*, which, with the nucleus, are more readily soluble in alkalies; and 3, the granular matters which are wholly insoluble in alkali. The last remain after the entire solution of some of these tissues, and by no means consist entirely of fat.

They all contain a considerable amount of unoxidized sulphur, and usually about one per cent. of mineral substances in all.

SECTION I.

EPITHELIUM (EPIDERMIS, ETC.).

Every free surface of the body is covered by one or more layers of cells, constituting an *epithelium*.[1] Epithelium, therefore, enters into the structure at every point of the skin, and of serous and mucous membranes, forming the outermost (*i. e.* farthest from the vessels), of the three layers of which they are alike composed. The next layer underneath the epithelium is the basement-membrane, already described (p. 111), and the innermost, the corium. Viewed in its histological relations, therefore, epithelium may be defined to be a *continuous expansion of cells; consisting of one or more strata developed upon and completely covering a basement-membrane.* A single layer of cells constitutes a *simple*, and two or more *layers* a *compound* epithelium.

The epithelium of the skin is usually called epidermis or cuticle. These terms, however, include only the outer layers of the cutaneous epithelium, as will be shown. The epithelia of the skin and of mucous membrane, are of course continuous where these membranes are so; as at the mouth, nostrils, anus, &c.

Epithelial *cells* present no original peculiarities of *form* and *contents*. They consist of cell-wall, contained fluid, granules, nuclei, and nucleoli (p. 114). On some portions of the mucous membrane, however, they assume a conoidal or elongated (cylindrical) form; while on serous membranes the contact of the opposed surfaces gives them a very flat form, allowing but a small amount of fluid con-

[1] From ἐπί upon, and θηλή the nipple—it being very apparent on this part.

tents; and on the skin the outer strata of cells become dried and collapsed into solid horny scales. In the first instance, the epithelium is termed a *conoidal* (or cylinder), and in the latter case, a *scaly* epithelium. Between the conoidal and the flattened cell, many varieties are found; the globular and the polyhedral form predominating.

Again, the conoidal cells are sometimes found surmounted by cilia,[1] so called; in which case we have a *ciliated* epithelium.

The conoidal (or cylinder) and the ciliated epithelium are found only on the mucous membrane, in the adult human body; the scaly variety exists everywhere on the skin and serous membranes, and also on certain parts of the mucous membranes, hereafter to be specified.

The *granules* are more numerous in epithelial cells in proportion as the latter are smaller and younger, and in these also the circular or oval nuclei are more apparent. Acetic acid renders them very distinct. Indeed, the granular appearance and the distinctness of the nuclei seem to measure the functional activity of the cells, and when both disappear the cells become detached or desquamated.

The *size* of epithelial cells varies according to their form, and also in different parts of the body, and in the different layers in the same part. The conoidal cells of the epithelium of the small intestine are $\frac{1}{1125}$ to $\frac{1}{925}$ of an inch in length, and $\frac{1}{3750}$ to $\frac{1}{2800}$ of an inch broad. The cells in the most superficial layer of the conoidal epithelium of the larynx are $\frac{1}{750}$ to $\frac{1}{560}$ of an inch long, and $\frac{1}{4500}$ to $\frac{1}{2800}$ of an inch broad. In the very lowest layers of the epithelium of the mouth, when the cells are arranged nearly perpendicular to the basement-membrane, they are $\frac{1}{1870}$ to $\frac{1}{1400}$ of an inch long; in the middle layers they are $\frac{1}{2800}$ to $\frac{1}{2250}$ of an inch broad, having become somewhat flattened; while the most superficial cells are large flattened plates, called *epithelial plates*, by Kölliker—$\frac{1}{560}$ to even $\frac{1}{300}$ of an inch across. (Fig. 147.)

The *thickness* of the epithelium must depend on the size of the cells and the number of layers. The small intestine, having but a single layer, will have an epithelium $\frac{1}{1125}$ to $\frac{1}{925}$ of an inch thick, as has been shown. The compound epithelium of the mouth is $\frac{1}{112}$ to $\frac{1}{56}$ of an inch thick; and that of the larynx is $\frac{1}{468}$ to $\frac{1}{280}$ of an inch thick.

[1] From "Cilium," an eyelash; since they resemble fine hairs.

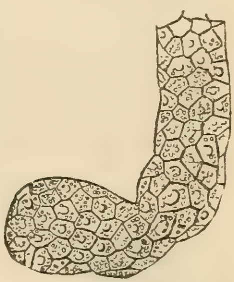
Varieties of Epithelium.

Both the *scaly* and the *conoidal* epithelium present two varieties, the *simple* and the *compound*. The conoidal epithelium is also in some parts *ciliated*, whether simple or compound. Thus we find—

I. The simple scaly epithelium.
II. The compound scaly epithelium.
III. The simple conoidal epithelium.
IV. The compound conoidal epithelium.
V. Either of the two preceding may be ciliated.

Frequently the cells of a scaly epithelium (as on serous membranes) are matched together in such a way that its free surface resembles mosaic or a pavement, when seen under the microscope, the cells being polygonal and mostly hexagonal. This appearance has given rise to the expression "pavement or tessellated" epithelium. But the free surface of a conoidal epithelium often presents the same appearance; and since it depends not on the size of the cells, nor even their form, except so far as their free surface is concerned, there is no sufficient reason for making this appearance a distinguishing characteristic. It is indicated in Fig. 139.

Fig. 139.



Tessellated (scaly) epithelium of a tubulus uriniferus.

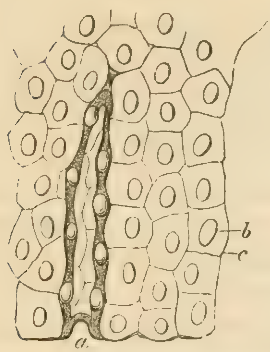
Todd and Bowman have described the epithelium lining the minute ducts of the true glands as consisting of globular cells, and hence term this "globular or glandular" epithelium. They suppose that the secretion of the gland is secreted by these cells alone. Since, however, all epithelial cells secrete in proportion to their size and fluid contents, this distinction is unnecessary. Besides, these cells are not by any means uniformly globular. There are all intermediate phases, so far as the form of the cells is concerned, between the flattened or scaly and the conoidal or cylindrical.

It will appear that different functions are assigned to these different varieties of epithelium, now to be described.

I. Scaly Epithelium.

A. The *simple scaly* or squamous epithelium consists of a single layer of flattened cells, of a polygonal outline. Fig. 140 shows the epithelium of a serous membrane.

Fig. 140.

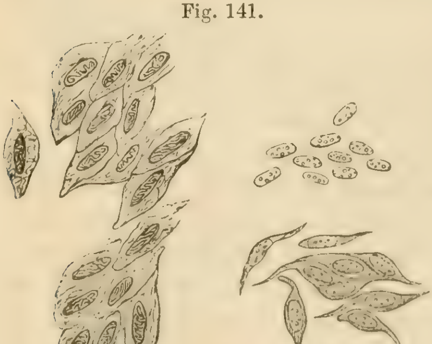


Scaly epithelium of serous membrane. *a.* A fold showing thickness of the cells at its dark edges. *b.* One of the nuclei. *c.* Line of junction of two cells. (Magnified 300 diameters.)

Distribution.—This kind of epithelium is found covering all true serous (but not synovial) surfaces. It also lines all lymphatics and bloodvessels throughout, and all mucous follicles, the air-cells of the lungs, and the ultimate follicles of all true glands. It also covers the membrane of Demours, the posterior surface of the iris (uvea), the inner surface of the choroid coat (the pigment-cells described on page 133, there forming a scaly epithelium), and the capsule of the crystalline lens; and lines the internal ear and the Graafian vesicle.

The simple scaly epithelium lining the seminiferous tubes merges into the simple conoidal at the head of the epididymis, and thence the latter variety lines the vas deferens.

Fig. 141.

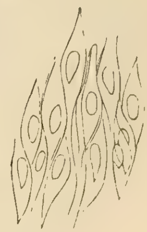


Epithelial cells of aorta (horse). The largest, with dark nuclei, are magnified 400 diameters; the others 200 diameters. The 10 smaller at the right are mere nuclei.

Peculiarities.—In some of the large arteries and some of the veins, the epithelial cells are quite irregularly elongated, fusiform, and slender, being $\frac{1}{1125}$ to $\frac{1}{560}$ of an inch long. Being also not perfectly matched to each other, narrow spaces are here and there left between them. (Fig. 141.) Distinct and well-marked epithelium may be traced in vessels only $\frac{1}{1125}$ to $\frac{1}{1600}$ of an inch in diameter. In the walls of the capillaries, however, only scattered nuclei can be seen; which,

increasing in number and development as the vessels increase in size, may be the rudiments of epithelial cells. Fig. 142 shows the epithelium of the lymphatic vessels.

Fig. 142.



Nucleated epithelial cells of lymphatics of a horse. (Magnified 320 diameters.)

The epithelial cells of the salivary glands contain a greater amount of fatty and pigment-granules than occur in most mucous glands.

The cells of the seminiferous tubes are smaller before puberty. At that period they increase, and assume a higher function—the secretion of semen. They merge into conoidal epithelium at the head of the epididymis, as already stated.

The epithelium of the left ventricle and auricle of the horse is seen in Figs. 143 and 144.

The epithelium of the Graafian vesicle constitutes what is termed the "membrana granulosa," and con-

Fig. 143.

Epithelium of left ventricle of a horse. (Magnified 200 diameters.)

Fig. 144.

Epithelium of left auricle of a horse, showing the rounded and the pointed forms of the cells. (Magnified 200 diameters.)

sists of roundish, polygonal, nucleated cells, $\frac{1}{3750}$ to $\frac{1}{2812}$ of an inch in diameter. They become club-shaped about the time the ovum

Fig. 145.

Membrana granulosa of ovum of bitch during heat. A. The elongated form and stellate arrangement of its cells around the zona pellucida. B. The same ovum after the removal of most of its club-shaped cells.

leaves the ovary. They contain yellowish fatty granules, which become indistinct after the death of the animal. (Fig. 145.)

The epithelial lining of serous membranes (Fig. 140) gives their surface a glassy lustre, and lubricates it by its secretion. A part, however, of the serum in serous cavities—the water more especially—doubtless enters them by mere transudation from the blood-vessels. In inflammations the epithelium is detached, and the surface of the membrane then becomes somewhat rough, and of a dull, leaden hue.

Kölliker asserts that this kind of epithelium is, in the ventricles of the brain of embryos, surmounted with cilia.

B. *Compound Scaly Epithelium.*

This kind of epithelium consists of several layers of cells, the outermost of which assume the form of dry scales, or become very much flattened cells. (Fig. 146.)

Distribution.—Compound scaly epithelium covers the synovial membranes generally. On the mucous membrane it is found lining the alimentary canal from the lips to the cardiac orifice of the stomach, and the lower half or more of the rectum. It also extends into the nostrils a short distance, and lines the lachrymal canals, the conjunctiva, and the cavity of the tympanum, except the inner surface of the membrana tympani. It extends through the female urethra, the vagina, and the lower third of the cavity of the uterus (but not through its neck), and covers the clitoris and nymphæ. Finally, it lines the bladder, ureters, and pelvis of the kidneys, in both sexes.

Fig. 146.

Vertical section of epidermis of palm of hand. *a*. Outer portion, composed of flattened scales. *b*. Inner portions, of nucleated cells. *c*. Portion of perspiratory duct. (Magnified 155 diameters.)

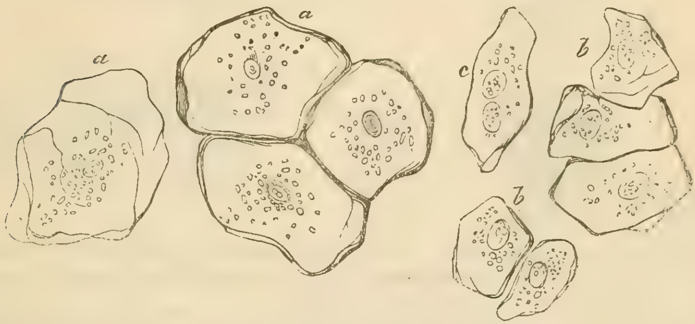
The compound scaly epithelium also everywhere forms the outer layer of the skin, and is here called the epidermis. In the latter the scales are dry and horny, as before stated. Figs. 146 and 68 show its vertical section; the entire epithelium of the skin including both the epidermis and the rete mucosum, as it is improperly called.

Peculiarities.—The epithelium of the skin

varies much, in different parts, in thickness. Its outer portion constitutes the *cuticle*, and its inner part the *rete mucosum*, or stratum Malpighii, of anatomists.

The outer layers of cells in case of the mucous membrane also become flattened into coherent scales (the epithelial plates). These may be detached in flakes or sheets from the œsophagus, and are often so by disease, from the tongue. (Fig. 147.) The epithelium

Fig. 147.



Epithelial plates of oral cavity. *a*. Large. *b*. Middle-sized. *c*. Same, with two nuclei.—Magnified 350 diameters. (*Kölliker*.)

upon this organ is sometimes even $\frac{1}{56}$ of an inch thick. Still, it is very endosmotic, various fluids penetrating it from without, and the blood-plasma also exuding through it from the vessels which underlie it. (*Kölliker*.)

In the *lower animals* we find various modifications of this epithelium—as in the sheaths of the beaks of birds and of Chelonian reptiles; in the scales of fishes; in the jaws of certain invertebrate animals; in whalebone so-called, tortoise-shell, and the teeth of some fishes; in the spines and plates of the tongues of many animals, and the spines of the œsophagus of the Chelonia; in the teeth-like appendages of the stomachs of some of the mollusca, and the horny plates of the gizzards of most birds, and of the cardiac half of the stomach of the horse.

II. Conoidal Epithelium.

A. *Simple Conoidal Epithelium.*

This variety of epithelium, consisting of a single layer of conoidal cells, is represented by Figs. 148, 149, and 150.

Distribution.—It commences at the cardiac orifice of the stomach,

and lines the whole alimentary canal thence to the rectum (Kölliker says, to the anus). It lines the excretory ducts of all glands; the

Fig. 148.

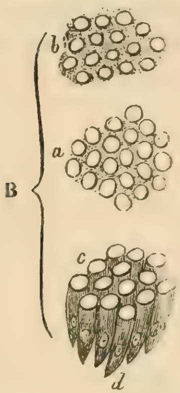


Fig. 149.

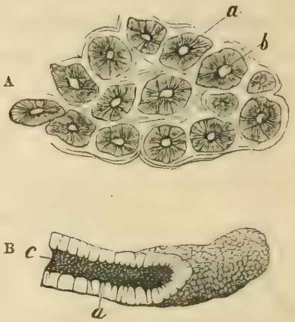


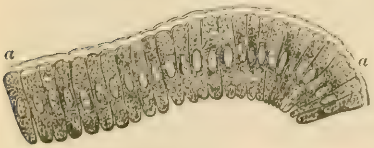
Fig. 148. Simple conoidal epithelium of inner surface of stomach and its favuli. *a*. Free ends of epithelial cells. *b*. Nuclei visible at a deeper level. *c*. The free ends seen obliquely. *d*. Deeper ends of do. near which are the oval nuclei (300 diameters.)

Fig. 149. Simple conoidal epithelium of Lieberkuhn's follicles. *A*. Transverse section of follicles showing (*a*) the basement-membrane, the epithelium, and the inter-follicular areolar tissue, (*b*) cavity or lumen of the follicle (200 diameters.) B. Single tube showing (*a*) basement membrane, and (*c*) internal surface of the wall of the tube (200 diameters).

sinuous fossæ (mucous glands) of the cervix uteri; the male urethra and all ducts opening into it, and the vas deferens to the head of the epididymis. Its appearance in the gastric tubes is shown by Fig. 148.

It is also *ciliated* in all the following parts—the finest bronchial tubes, and all the sinuses (frontal and maxillary), and the cells (sphenoidal and ethmoidal), of the face; on the inner surface of the membrana tympani; the upper two-thirds of the cavity of the uterus, and through the Fallopian tubes, and the canals in the Wolffian body in the fœtus.

Fig. . 150



Simple conoidal epithelium from intestinal villus of a rabbit. *a*, *a*. Membrane connecting the free surfaces of the cells, raised by the action of water.

Peculiarities.—The fact that this kind of epithelium lines the uterine glands, is an exception to the law before stated, that the ultimate follicles of all glands are lined by simple scaly epithelium. (*Kölliker.*)

If several of these cells still cohering, after being detached from

the subjacent membrane, are treated with water, they seem to be surmounted by a delicate membrane. This is, however, merely a continuous sheet formed by the ends of the cells; they having been separated by the endosmosis of the water. (Fig. 150.)

B. *Compound Conoidal Epithelium.*

This variety consists of two or more layers of cells, the outermost being conoidal. It is shown by Figs. 151 and 152. Wherever found it is always *ciliated.*

Fig. 151.

Fig. 152.

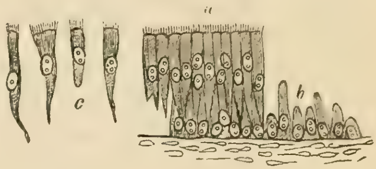


Fig. 151. Simple conoidal ciliated epithelium. *a.* Nucleated cells. *b.* Cilia and their free extremities.

Fig. 152. Compound conoidal ciliated epithelium of nasal passages. *a.* Superficial series of ciliated cells. *b.* Deeper series becoming elongated vertically. *c.* Various shapes of deepest ciliated cells. (180 diameters).

Distribution.—Commencing about three-quarters of an inch within the nostrils, it extends through the nasal passages, covers the upper part of the pharynx and posterior surface of the soft palate; then enters the larynx to line that, the trachea, and the bronchial tubes to their finer subdivisions. It also lines the Eustachian tube, and the lachrymal duct and sac.

Ciliated Epithelium.

Epithelium is so called when the outer layer of cells are surmounted by cilia. These, seen under the microscope, resemble very fine hairs, and the average number attached to each cell is 10 to 22. (*Valentin.*) They grow from the free (or outer) extremity of the cells, and are generally so arranged as nearly to cover it, though sometimes but a single one is found. They are fine, soft processes of the cell-membrane, broader at their base and terminating in a point. They are in incessant motion; constantly striking forward from a vertical position to very nearly a horizontal one, and instantly returning again. The author counted one hundred and forty such strokes in a minute, in case of cells from the pharynx of

a frog. It has been asserted that they all strike *towards the outlet* of the passage on which they are found; an assertion needing confirmation however. The motion seems to depend much upon the state of the cells in respect to fluidity; since it will continue many hours after death (even 78), in case of man (*Gosselin*), if the cells are kept moist.[1] The cilia are among the most minute objects occurring to the histologist; being $\frac{1}{7500}$ to $\frac{1}{5454}$ of an inch long, and not exceeding $\frac{1}{40,000}$ to $\frac{1}{20,000}$ of an inch in diameter. They were discovered by Purkinje and Valentin in 1834. Figs. 151 and 152 show them on both kinds of conoidal epithelium. (Also Fig. 91.)

Distribution.—It has been seen that the ciliated epithelium (either simple or compound conoidal), lines the whole extent of the air-passages from just within the nostrils to the termination of the finest bronchial tubes, and the communicating cavities also; as the sinuses and cells of the face, Eustachian tube, and membrana tympani, and the ductus ad nasum and lachrymal sac.

Further than this, the ciliated epithelium lines the upper two-thirds of the cavity of the uterus, and the Fallopian tubes throughout. The canals in the Wolffian bodies of the fœtus must also be added.

Peculiarities.—It is an interesting fact that the epithelium of the upper part of the uterus and of the Fallopian tubes is not ciliated previously to puberty.

Disease respects the distinctions made in regard to the different varieties of epithelium. In croup, the nasal passages are almost invariably first affected, and the disease follows the course of the ciliated epithelium over the posterior surface of the velum, and thence into the larynx and trachea, and *not* along the œsophagus into the stomach. Again, a disease commencing in the lower half of the pharynx, or the tonsils, does not soon extend to the larynx and trachea, as a general rule. Besides, the uterine glands may be diseased for an indefinite period without the disease extending either to the uterine cavity or to the vagina; its conoidal epithelium being bounded both above and below by the scaly variety.

Development of Epithelium.

The first cells laid down to form an epithelium are probably de-

[1] The motion of the cilia is destroyed by many chemical and mechanical agents; and Virchow has recently found that a solution of potassa or soda *re-excites* it. He infers from his experiments that the substance of the cilia nearly approximates musculine.

veloped according to the method first described (page 120), *free* cell-development; they being formed in a plasma exuded upon the basement-membrane.[1] They subsequently multiply by the *fissuration* of the cells and nuclei in the lower layers. They are constantly growing, and on reaching maturity, they lose their vitality and become detached or desquamate. In the mouth and alimentary canal they are detached also by mechanical causes.

The *reparation* of epithelium also takes place by fissuration, unless all the layers of cells have been removed; in which case there is doubtless a development *de novo*, as at first. Sometimes, however, a long time is required for the formation of a perfect epithelium: as is seen especially upon the surface of cicatrices after entire loss of the skin.

Functions of Epithelium.

The functions of epithelium vary with the different varieties, and also in different parts of the body.

I. The *scaly* epithelium is specially for *secretion* and *protection.*

The simple scaly epithelium of serous membranes, mucous follicles and glands, and, in part, of the eye and the internal ear, and the compound scaly epithelium of synovial membranes—are for secretion of serous or mucous fluids, as the case may be.

The simple scaly epithelium of the lymphatics and bloodvessels, of the ocular membranes, not alluded to in the preceding paragraph, and of the Graafian vesicle; the compound scaly epithelium extending from the lips to the cardia, at the commencement of the nostrils, on the lachrymal ducts, conjunctiva, and tympanic cavity; that covering the vulva, vagina, and lower third of the uterine cavity; and that lining the bladder, ureters, pelvis of the kidney and female urethra—are for protection, and doubtless also, to some extent, for secretion.

The compound scaly epithelium of the skin—*the epidermis*—is almost exclusively protective.

II. The *conoidal* epithelium is for secretion, absorption, or protection.

The simple conoidal epithelium extending from the cardia, through

[1] It has been suggested that the fusiform slender epithelial cells of the larger arteries and some veins, are related in their development to the striped lamellæ which underlie them.

the alimentary canal, nearly to the anus, is both secretive (of mucus) and protective. The cells covering the villi are also believed to be subservient to absorption of alimentary materials into the blood. Indeed, epithelium is everywhere remarkably endosmotic. In the cervix uteri it is more especially for secretion; in the excretory ducts of all glands, secretive and protective; as it is also in the male urethra and all ducts opening into it, and in the vas deferens.

Ciliated epithelium (whether simple or compound conoidal) owes its peculiarities to its cilia. Independently of them, it may be, and probably always is, secretive and protective. It lines only the whole of the air-passages (except the air-cells), and the passages opening into them, and a part of the genital passages of the female. Its peculiar function, in the former case, seems to be to secure the contact of new portions of air in the air-passages, air-cells, and others, to subserve the function of aeration. The cilia may also aid in preserving a due state of moisture on every part of a membrane, or to prevent occlusion of narrow passages by a normal or abnormal secretion—as in the Eustachian tube, the lachrymal duct and sac, the finest bronchial tubes, and the Fallopian tubes.

It has been suggested that the cilia on the cells covering the upper two-thirds of the uterine cavity, and lining the Fallopian tube, carry the semen to the ovary to secure impregnation; and that, by a reversed action, they also return the impregnated ovum to the uterine cavity, where it remains to be developed during the period of gestation. Though this idea of reversed action is purely hypothetical, it is still probable that the cilia have reference to the function of menstruation or impregnation, or both, since they are not developed till the period of puberty arrives. But it is a gratuitous assumption that the cilia of the cavities in the face (antrum, &c.) are subservient to smell, since we know that the olfactory nerves are not distributed to these cavities at all.

Since *secretion is in all cases performed by epithelial cells*, all the normal secretions contain them, or at least their nuclei or their *debris;* as has already been seen in the description of them respectively in the Second Division of this work.

Epithelium is corrugated and rendered opaque by the action of alcohol, and hence the effect of holding brandy, &c., in the mouth. In some diseases it becomes entirely detached; and thus is produced the extreme redness of the tongue which is so often met with. An irritable condition of the mucous membrane of course results from

its removal. Nitrate of silver blackens the epidermis and renders opaque the epithelium of mucous membranes, but destroys nothing beneath them. It is therefore not a *caustic*, in any scientific sense.

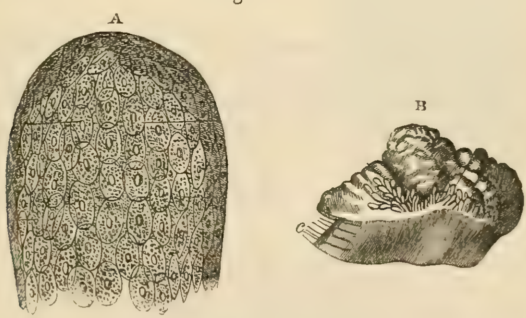
The epidermis is separated from the corium by a blister, and by exudations underneath it from other causes—as in all vesicular skin diseases.

Pathological Conditions of Epithelium.

1. Epidermic and epithelial tumors (epithelioma) are of very frequent occurrence. Warts (verrucæ) and callosities of the skin, especially corns (clavi), are minor instances of this group. In the case of warts, however, the papillæ as well as the epidermis become hypertrophied. The wart-like nævi materni, ichthyosis, and elephantiasis Arabum, also belong to this class, though this last is not limited to the epidermis alone.

2. Condylomata (more properly termed *papillomata*), mucous tubercles, and similar vegetations, apt to form around the orifices of mucous canals from the irritation of syphilitic or other discharges, belong also to this class. Fig. 153, B, shows one of these vegetations

Fig. 153.



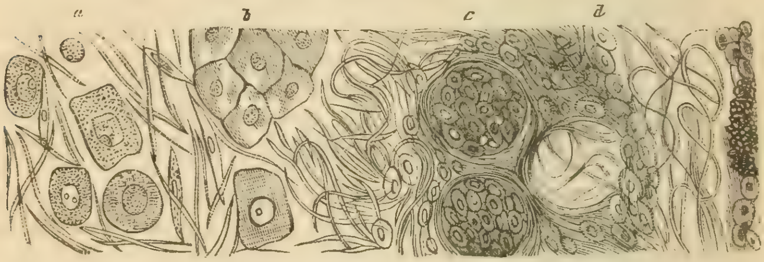
Epithelial new formations. A. Papilloma highly magnified. B. Epithelial tumor from lip. (*Lebert.*)

as figured by Lebert; it being a papilla formed by a layer of closely imbricated epithelial scales, the deeper portions consisting of less flattened cells, or nuclei in an amorphous blastema, and extending to the corium of the skin. Horns are also epidermic productions, and sometimes appear on the human body. They originate in the sebaceous follicles, whose epithelium, thrown off in abundance and together with fatty secretion, forms a conical mass which protrudes from the skin (usually of the head or of the forehead), sometimes even to the length of six inches.

3. *Epithelial cancer* should be distinguished from mere epithelioma; the former being doubtless malignant, though not so certain to affect the lymphatic glands, and the body generally, as the other forms of cancer. It occurs on the skin and mucous membrane, the

cheek and lips being its most common seat. On the skin it is generally a hard, well-defined tumor, irregularly nodulated, and covered with minute watery papillæ. On a mucous surface it appears as a cauliflower-like growth, more or less red from vascular injection, variously consistent, and easily separated into parts by pressure. In either case the papillæ and the epithelium covering them become greatly hypertrophied; the corium and areolar tissue also becoming

Fig. 154.

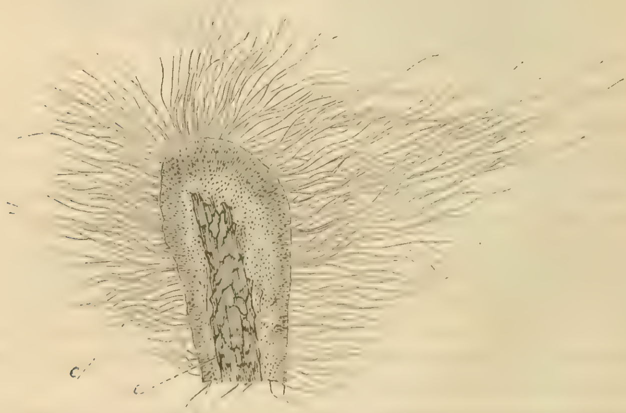


Section of epithelial cancer of the cheek. *a.* Epidermic scales, and fusiform cells and fibres on the external surface. *b.* Group of epidermic scales. *c.* Areolar tissue of the corium. *d.* Cancer-cells in the latter tissue. (*Bennett.*)

converted into a fibroid substance. Fig. 154 shows the microscopic structure of an epithelial cancer of the cheek.

4. *New formations* of epithelium are common in certain pathological cysts. A very delicate ciliated epithelium has been found on

Fig. 155.



Oidium albicans. *a.* A mass of epithelial cells covered with the granular matrix of the fungus (*b*), from which a luxurious growth of mucedinous filaments (*c*) proceeds.—Magnified 350 diameters (*Kölliker.*)

the intersaccular partitions in ovarian tumors, and in those of the testis.[1]

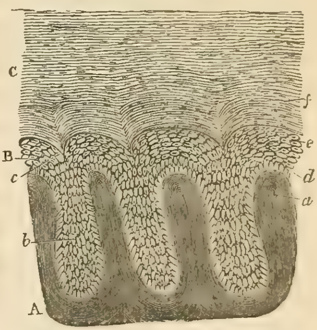
5. Some of the peculiar appearances of the tongue in disease are due to changes in its epithelial cells. They may even become a nidus for the development of parasitic vegetation; of which the peculiar white coat produced by the oidium albicans (Fig. 155) in some cases of diphtheritis, is an illustration.

SECTION II.

THE NAILS.

Nails are merely a modification of the epidermis, being histologically a very much condensed compound scaly epithelium. (Fig. 156.) They are also, by maceration, detached in continuity with it. And, according to Mulder's investigations, they differ from epidermis in chemical composition, only in containing a larger proportion of sulphur and carbon.

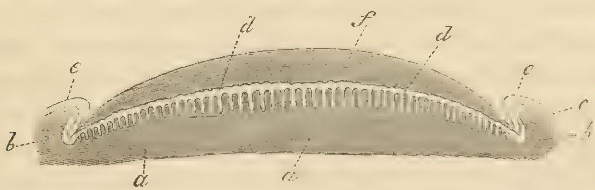
Fig. 156.



Transverse section of nail and its matrix. A. Skin. B. Stratum Malpighii of nail. C. Horny layer of same. *a.* Papillæ of nail-matrix. *b.* Cells of the Malpighian stratum. *c.* Ridges of horny substance of nail. *d.* Deepest layer of perpendicular cells of Malpighian layer. *e.* Upper layer of flattened cells of the same. *f.* Nuclei of the true nail substance.

The surface covered by the nail, and upon which it is developed, is called the *bed* of the nail. A transverse section of it, and of the nail also, is seen in Fig. 157. It presents a series of peculiar ridges on its surface, beginning under the root of the nail, and at first radiating outwards from the centre for a distance of $2\frac{1}{2}$ to $3\frac{1}{2}$ lines; whence they become parallel and more prominent, and take

Fig. 157.



Body and bed of nail, transverse section. *a.* Bed of nail, with its ridges. *b.* Corium of lateral portion of wall of the nail. *c.* Stratum Malpighii, with its ridges (white). *d.* Papillæ. *e.* Cuticle of wall of the nail. *f.* Horny layer of nail, with short notches on its under surface.—Magnified 8 diameters. (*Kölliker.*)

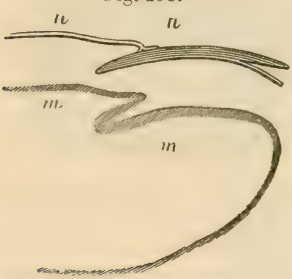
[1] London Lancet, Sept. 1856.

on the form of true laminæ, $\frac{1}{500}$ to $\frac{1}{120}$ of an inch deep. The line of transition of the ridges into the laminæ divides the bed of the nail into two sections, differing in color and in extent; the posterior smaller one underlying its root and *lunula*, and the other portion its body. The ridges and laminæ number from fifty to ninety. At their edges they are beset with a series of short papillæ. On the little toe, however, the papillæ are frequently not seated upon the ridges, but are dispersed. (*Kölliker.*)

The *wall* of the nail is the process of the skin continuous with the bed of the nail, laterally and posteriorly; forming the folds on the sides, by which the nail is limited. The corium of the wall and of the bed of the nail contains but little fat; but in the ridges and the laminæ is an abundance of fine elastic fibres. The capillaries, $\frac{1}{2400}$ to $\frac{1}{1500}$ of an inch in diameter, form simple loops in the papillæ; and the nerves have the same relation as in the skin.

The nail itself is divided into the body, the root, and the free edge. These are shown by Fig. 158. The *lunula* is the opaque semilunar portion of the nail (not seen in all cases), at its posterior part. When not apparent, it is covered entirely by the fold of the skin underneath which the root of the nail lies, and which is called the *matrix* of the nail.

Fig. 158.



Relations of nail to the cuticle. *n*, *n*. Cuticle and nail; *m*, *m*. Corium and bed of nail.

The lower surface of the nail corresponds with the surface of the ridges and laminæ of the bed. Furrows and ridges therefore appear on the former as upon the latter. It is by the mutual interlocking of these opposite surfaces that the intimate union of the nail with the corium of the skin is effected. (Fig. 157.)

In *structure*, the nails, like the epithelium of the skin, consist of two layers; the deeper being soft (the Malpighian layer, sometimes improperly called the *stratum mucosum*), and the superficial, constituting most of the thickness of the nail (the *horny layer*). This stratum consists wholly of cells, like that of the epidermis (except that they are nucleated); and in the negro is black. Hassall states that the younger cells of this layer generally contain pigment in the white races. The horny layer is quite smooth on its under surface at the root, but becomes ridged further forwards; the ridges

appearing in transverse sections as pointed processes, $\frac{1}{1200}$ to $\frac{1}{600}$ of an inch in length, and even $\frac{1}{300}$ to $\frac{1}{200}$ of an inch at the edge of the nail. The upper surface also frequently shows distinct parallel longitudinal streaks, appearing as the almost effaced impressions of the laminæ below.

The nail increases in thickness from the root to near the free edge, being at least three times as thick anteriorly as posteriorly ($\frac{1}{40}$ to $\frac{1}{30}$ of an inch).

Unprepared sections of nails give very little indication of any structure whatever. But on boiling them in dilute caustic soda, they at once display a beautiful arrangement of cells, like a scaly epithelium, but nucleated; these being flatter in the superficial than in the deeper layer, and not more than one half as thick. One or several layers of these cells constitute a lamella; and the lamellæ closely united and not sharply defined, form the whole of the horny substance. The greater hardness of nails as compared with epidermis, is said by Lauth to be due to a greater proportional amount of phosphate of lime in the former.

The nails continue to *grow* only so long as they are cut. Remaining uncut, they attain to the length of one and a half to two inches, and curve over the ends of the fingers and toes. Among the Chinese, of whom the literary class never cut the nails, the length is, according to Hamilton, two inches. The growth takes place at the expense of the cells in the Malpighian layer, both at the edge of the root and under the body of the nail. Thus, the latter becomes longer and thicker at the same time. The longitudinal growth is, however, by far the most rapid; since the first round cells become more and more flattened and elongated as they move forwards and upwards from their first position.

The time necessary for a nail to grow its whole length, varies in different parts from twelve to twenty or more weeks; and hence this length of time is required for the formation of a new nail.[1] The nail is thicker on its most convex portion than at its edges.

If the changes in the nail cells are investigated as compared with those of the epidermis, a striking similarity is discovered. 1. The original cell-membranes (those of the Malpighian layer) become

[1] According to M. Beau, the nails of the fingers grow four times as rapidly as those of the toes; the thumb growing two-fifths of a line per week, and its whole length in twenty weeks—while the nail of the great toe requires ninety-six weeks, or nearly two years, to grow its length. The portion of a nail growing during a disease is thinner than the rest, as is shown by a transverse groove or depression

harder, and more phosphate of lime is deposited in them or within the cells. 2. Like the horny cells of the epidermis, they become flattened and increase longitudinally and transversely. 3. They coalesce more completely, so that they cannot be separately recognized. But their nuclei do not disappear as do those of the epidermis; and herein is a characteristic distinction.

The nails are constantly suffering loss from friction and other causes. Much of the matter accumulating under them consists of epithelial cells.

The *development* of the nails commences in the third month of intra-uterine life; they not being at first distinguishable from a soft epidermis. The ridges of the bed of the nail are well marked at the end of the fourth month. They cover the whole bed, and have assumed the consistency of a nail at five months, and reach the extremities of the finger at eight months.

The free edge of the nail of the new-born infant is cast off once at least (Weber says many times), soon after birth; probably from external violence which it is too delicate to resist. This free edge appears to be a nail of an earlier period, probably of about the sixth month, which has been thrust forward in the course of development. Six or seven months after birth the first set of nails is completely replaced by new ones (*Kölliker*); and at two or three years the horny layer is not distinguishable in appearance from that of the adult.

Nails, when destroyed, are almost always imperfectly regenerated, on account of injury done to the laminæ and vessels. A rudimentary nail sometimes appears on the second phalanx of a finger in case of loss of the first. In some rare cases, a periodical loss and regeneration of the nails occurs.

The hoofs and claws of the lower animals are the analogues of the nails, both physiologically and histologically.

Uses of the Nails.—The nails support the pulp of the fingers and toes, and thus conduce to the perfection of touch. They also increase the power of the fingers as prehensile organs; and in a state of nature at least, (*i. e.* if remaining uncut), they become not inefficient means of attack and defence.

Pathological States of the Nails.

Any abnormal condition of the bed of the nail will, of course, affect the growth of the latter. In the lamellated nails of old people, Kölliker found all the capillaries in the anterior segment of the

bed closely filled with fat-granules of various sizes. It is an interesting fact, and not well explained, that the nails become deformed (curved toward the free edge), in phthisis and cyanosis. In the rabbit, it was found by Steinrück that the division of the ischiatic nerve caused the nails and hair to fall off.

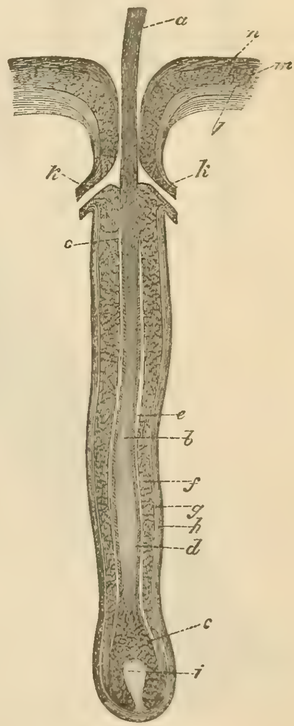
SECTION III.

THE HAIR.

Each hair consists of its shaft (*scapus*), and the root; the former including all that projects free from the surface of the skin; the latter, the portion beneath the surface. (Fig. 159.) The bulb is the deepest portion of the root, and is from $1\frac{1}{2}$ to 3 times the diameter of the shaft.

A. The *shaft* in straight hairs is rounded and straight; undulated and flattened in the wavy; and spirally twisted and flat, or slightly ribbed, in curly and woolly hairs. It consists of 1, the cortical or *fibrous substance*, 2, the *cuticle*, and 3, the *medulla*, which is, however, often absent.

Fig. 159.

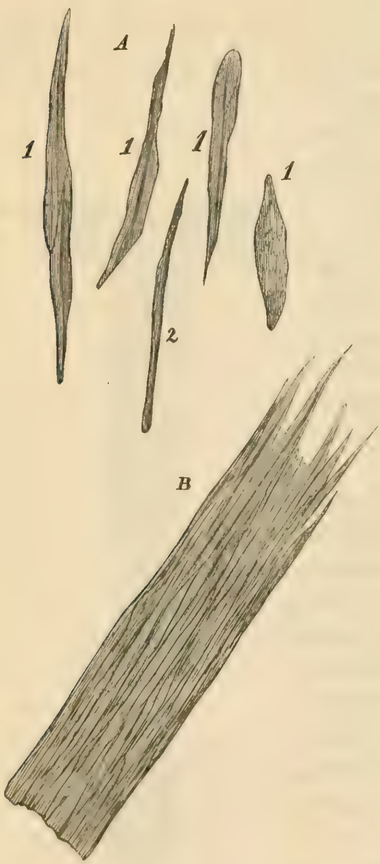


Structure of hair. *a.* The shaft. *b.* Root. *c.* Bulb. *d.* Epidermis. *e.* Inner root-sheath. *g.* Basement-membrane of hair-sac. *h.* Transverse and longitudinal fibrous layer of the sac. *i.* Papilla. *k.* Excretory duct of sebaceous glands, with epithelium. *l.* Corium at the aperture of the sac. *m.* Stratum Malpighii of the skin. *n.* Cuticle of do. somewhat retracted into the sac. *o.* Outer root-sheath. —Magnified 500 diameters. (*Kölliker.*)

1. The *fibrous substance*, which constitutes the greater part of the bulk of the hair, is striated longitudinally, streaked or spotted, and more or less colored, except in white hairs, in which it is transparent. The color is sometimes pretty regularly distributed through its whole substance; at others, concentrated in a few elongated granular spots. By the action of hot concentrated sulphuric acid, the fibrous portion of the hair is shown to be made up of flat, elongated fibres of various breadths ($\frac{1}{6000}$ to $\frac{1}{2400}$ of an inch), of marked rigidity and brittleness, and with notched margins and ends. In dark hairs, they have a dark tinge; in pale ones they are clear. These fibres are not, however, the ulti-

mate elements of the fibrous substance; each of them consisting of an aggregation of flat fusiform fibre-cells or plates—the *plates of the fibrous substance*—$\frac{1}{500}$ to $\frac{1}{333}$ of an inch long, $\frac{1}{6000}$ to $\frac{1}{3000}$ of an inch broad, and $\frac{1}{10,000}$ to $\frac{1}{7500}$ of an inch thick, with uneven surfaces and irregular edges. They very frequently exhibit a darker streak in the interior, and sometimes contain granular pigment. In other respects, they are homogeneous, and present no minuter elements. (Fig. 160.)

Fig. 160.



Plates, or fibre-cells of fibrous substance of the hair, treated with acetic acid. A. Isolated plates. 1. From the surface (3 single, 2 united.) 2. From the side. B. A lamella composed of many such plates.—Magnified 300 diameters. (*Kölliker.*)

The dark spots, dots, and streaks of the fibrous portion are of three kinds: 1, granular pigment; 2, cavities filled with air or fluid; 3, nuclei. The *pigment granules* are deposited in the plates of the hair, are especially abundant in dark hairs, and vary much in their size and form. The *cavities filled with air* appear in the form of round dots; $\frac{1}{30000}$ to $\frac{1}{15000}$ of an inch in diameter; or of longish streaks $\frac{1}{3000}$ of an inch in length, and $\frac{1}{30000}$ to $\frac{1}{15000}$ of an inch in breadth, running parallel with the axis of the hair. They are most frequent in white hairs, and often occur in fair, bright brown, and bright red hairs, in great numbers. They are absent in very dark hairs, and in the root of all hairs. The *nuclei* are, in dark hairs, commonly connected with the extremities of the pigment spots, and are $\frac{1}{1200}$ to $\frac{1}{750}$ of an inch long, by

$\frac{1}{24000}$ to $\frac{1}{10000}$ of an inch wide. Very similar appearances are, however, sometimes produced by the boundary lines of the hair-plates.

This description of the fibrous substance of the shaft applies also to that portion of the root which is solid and brittle. In the deeper and softer portions, the hair-plates are less rigid and have the form of more or less elongated cells with cylindrical, straight, or serpentine nuclei, easily rendered apparent by acetic acid. Finally, in the bulb they are merely round cells $\frac{1}{4000}$ to $\frac{1}{2000}$ of an inch in diameter; closely packed together, and, like the Malpighian layer of the epidermis, sometimes containing colorless granules, and sometimes so full of colored ones as to constitute true pigment-cells in appearance.

The *color* of the fibrous portion of the hair is due partly to granules of pigment, to some extent to the air-cavities, and partly to a pigment blended with the substance of the hair-plates. The granule-pigment presents all shades, from clear yellow through red and brown to black. The last mentioned, or diffused pigment, is quite absent in white hairs, and is scanty in clear fair hairs. It is most abundant in the more opaque fair hairs, and in red as well as in dark hairs; it alone sometimes producing an intense red or brown color. These two pigments vary in their proportion; but are about equal in very light and in very dark hairs.

2. The *cuticle* of the hair is a very thin, transparent pellicle investing the hair, and in intimate union with the fibrous substance. It consists of but a single layer, composed of plates arranged like tiles; and is $\frac{1}{6000}$ to $\frac{1}{4000}$ of an inch thick. Each plate is $\frac{1}{500}$ to $\frac{1}{428}$ of an inch in the transverse direction of the hair, and $\frac{1}{750}$ to $\frac{1}{600}$ in that of its length (Fig. 161, *d*, *d'*); and is only about $\frac{1}{24000}$ of an inch thick. On the lower part of the *root*, however, there are two layers of epidermis. (Fig. 162, *c*, *d*.) The cells of the outer layer are thicker than those of the inner, its whole thickness here being $\frac{1}{7500}$ to $\frac{1}{6000}$ of an inch; while the inner is $\frac{1}{4800}$ to $\frac{1}{3400}$ of an inch thick. Kölliker states that the two layers of epidermis pass into the outer nucleated cells of the bulb.

3. The *medullary substance* varies most of all of the constituents of the hair. It is a cord extending in the axis of the hair from near the bulb almost to the point. It is usually present in the thick, short hairs, and the stronger long ones, and the white hairs of the head; and absent in the down (*lanugo*) and the colored hairs of the head. It consists of from one to five columns of superimposed cells,

rectangular or quadrangular, and rarely rounded or fusiform, $\frac{1}{1700}$ to $\frac{1}{1200}$ of an inch in diameter, containing dark, fat-like granules, and a clear nucleus, $\frac{1}{7500}$ to $\frac{1}{6000}$ of an inch in diameter. The granules are, however, not fat nor pigment, but merely *air-vesicles.*

Fig. 161.

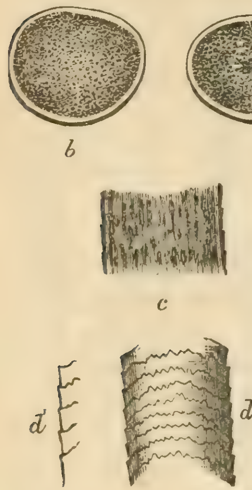


Fig. 162.

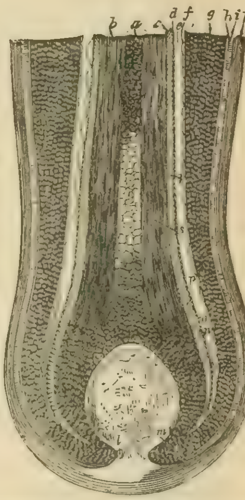


Fig. 161. Plates of cuticle of hair, &c. *a, b.* Transverse sections with and without pigment in the centre. *c.* A longitudinal section showing imbrication, and the pigment in the fibrous portion. *d.* Cortical plates showing edges. *d'.* Margin of same, showing their imbrication. (Magn. 150 diameters.)

Fig. 162. Hair-bulb, root-sheath, its epidermis, &c. *a.* Medulla containing air-cavities and indistinct cells. *b.* Fibrous substance. *c, d.* Inner and outer layers of cuticle. *e, f.* Inner and outer layers of internal root-sheath. *g.* External root-sheath. *h.* Basement membrane. *i.* Transverse fibre-stratum. *k.* Longitudinal fibre-stratum. *l.* Papilla. *m.* Lowest cells of hair-bulb continuous with those of external root-sheath. *n.* Perpendicularly placed nucleated cells, becoming non-nucleated near *p*, and continuous with the inner layer of the cuticle. *o.* Small perpendicularly arranged nucleated cells passing into the outer layer of the cuticle. *p.* Lowest portion of the inner root-sheath. *q.* Union of cuticle with fibrous substance. *r.* Commencement of the medulla in colorless cells. *s.* Part where the cells of the bulb begin to lengthen, to form the fusiform plates and cells of the shaft.

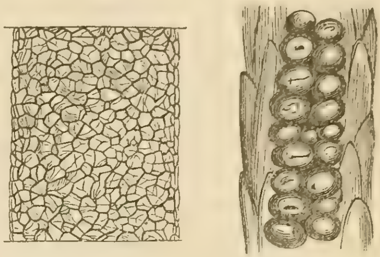
They vary, according to the hairs, from $\frac{1}{60000}$ to $\frac{1}{6000}$ of an inch in diameter, and occupy the medullary cells in great amount, existing both in white and in dark hairs. In the latter the air appears of a brown-red or brown tinge, from being seen through the colored fibrous substance; in white hairs it is of a silver white. It appears certain that the air may pass from one air-vesicle to another in the hair. Just above the bulb, and sometimes also in spots in the shaft, there are some of these air-vesicles, and therefore a paleness results. In some hairs, especially the red, there is often no definite line of demarcation between the fibrous portion and the medulla.

The medulla usually constitutes from one-fifth to one-third of the

whole diameter of the hair; being both relatively and absolutely thickest in short, thick hairs, and thinnest in the lanugo and the hairs of the head. It presents a rounded or flattened figure in transverse sections. (Figs. 161, *a*, and 163.) Very rarely the medulla is double throughout; but it is more frequently divided for a distance into two trunks, which soon unite again. In the Rodentia (beaver, squirrel, &c.) the medulla is divided by dissepiments; in the musk-deer it constitutes the entire hair, except a very thin cuticle, and in the sable its cells are very large. (Fig. 163.) The hair of the bat and the squirrel is shown by Fig. 164.

Fig. 163.

A B



Cells of medulla of Rodentia, &c. A. Hair of musk-deer, formed almost entirely of polygonal cells. B. Hair of sable, showing large rounded cells in the interior, covered by imbricated scales or flattened cells.

Fig. 164.

A B C

A. Small hair of squirrel. B. Large hair of squirrel. C. Hair of India bat.

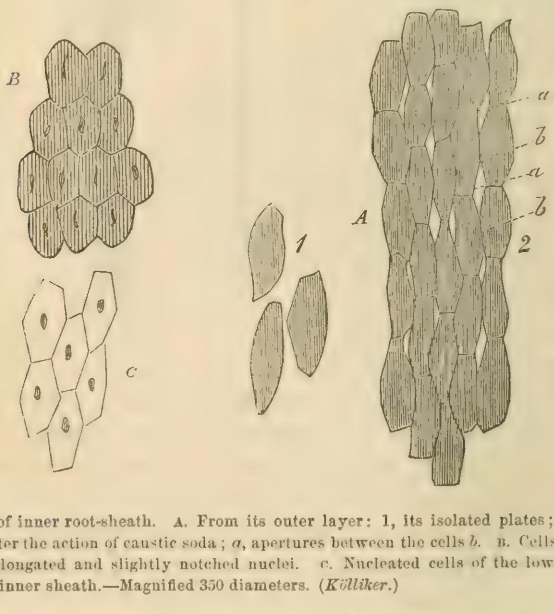
B. The *hair-sacs* are flask-like follicles, $\frac{1}{120}$ to $\frac{1}{40}$ of an inch long, extending into the upper layers only of the corium in case of the finest hairs; about one-half through it in case of those of medium size; and even through to the subcutaneous areolar tissue in case of the longest and strongest (the whiskers, on the head, pubes, and axillæ). They are merely involutions of the skin, at the bottom of which the hair-*papilla* is situated. They have therefore an internal epithelium or *root-sheath*, and an external or fibrous layer; the latter being continuous with the corium, and the former with the epidermis. (Fig. 162, *i*, *k*, and *e*, *f*, *g*.)

The *root-sheath*, or the epidermic investment of the hair-sac, is continuous with the epidermis around the aperture of the sac, and consists of two layers, an internal and an external. The *external* root-sheath (*g*) is continuous with the Malpighian layer (rete mucosum) of the skin, and rests on a distinct basement membrane; which, however, cannot be demonstrated between this and the internal fibrous

layer of the hair-sac, except on the lower half of the sac. At the bottom of the latter, the cells of this layer pass gradually into the round cells which cover the *papilla.* It is generally three to five times as thick as the inner layer; containing from five to twelve layers of cells, and terminating below in a very thin lamella.

The *inner* root-sheath (Fig. 162, *e*, *f*) is a transparent membrane, extending from the bottom of the hair-sac over more than two-thirds of it. It is connected externally with the external layer just described (*g*), and internally with the cuticle of the hair; being, in fact, blended with the latter (*c*, *d*). It is very dense and elastic, and consists, except in its lowermost part, of two or three layers of polygonal, elongated, transparent, and somewhat yellowish cells, with their longitudinal axes parallel to that of the hair. The cells forming the outermost layer of the two (or three), and which alone was formerly known, are elongated and without nuclei. Those of the innermost layer (Huxley's layer) are also polygonal, but shorter and broader, and always (in the lower half, at least, of the root-

Fig. 165.



Cells, &c., of inner root-sheath. A. From its outer layer: 1, its isolated plates; 2, the same in connection after the action of caustic soda; *a*, apertures between the cells *b*. B. Cells from the inner layer, with elongated and slightly notched nuclei. C. Nucleated cells of the lowest part (single layer) of the inner sheath.—Magnified 350 diameters. (*Kölliker.*)

sheath) possessed of distinct elongated nuclei. (Fig. 165.) This layer, however, also blends with the cells of the hair-bulb, like the exterior. (Fig. 162, *m.*)

Finally, the *papilla* of the hair (*l*) belongs to the sac, and corre-

sponds to a papilla of the skin. It is ovate or fungiform, $\frac{1}{96}$ to $\frac{1}{480}$ of an inch long, $\frac{1}{130}$ to $\frac{1}{240}$ of an inch broad, and is connected with the fibrous tissue of the sac by a pedicle. Its surface is perfectly smooth, and it consists, like the cutaneous papillæ, of an indistinctly fibrous tissue, with scattered nuclei and granules, but no cells. Neither Hassall, Günther, nor Kölliker has found in it either vessels or nerves. In some animals, however, the vessels may easily be seen; and we must not yet positively infer that they do not exist in the papillæ of human hairs also.

Chemical Composition of Hair.

This subject is still not sufficiently understood; but the hairs are chiefly composed of a nitrogenized substance (keratine), soluble in alkalies, and insoluble in boiling acetic acid. Mulder considers that 10 per cent. of sulphamide is combined with this nitrogenized compound. Scherer finds 10 per cent. of the hairs to be sulphur. Hairs also contain a considerable amount of dark or clear fatty matter. Chemical analysis does not discover any special pigment, though the microscope does, as has been seen (p. 255).

The ash of hair amounts to 1 to 2 per cent., in which are found oxide of iron (more in dark hair), oxide of manganese, and traces of silica. Jahn found phosphate of magnesia and sulphate of alumina in white hairs; and copper occurs in the greenish hairs of those who work in copper and brass. (*Langin.*)

Hairs withstand putrefaction better than any other part of the organism. Even those of mummies are found to be quite unchanged. Hence, also, the hair is preserved as a cherished relic of the departed. Metallic oxides color it as they do the epidermis. Hence the salts of silver and manganese blacken the hair, a sulphuret of these metals being produced. Chlorine bleaches it after prolonged action.

Wool and bristles do not differ essentially in composition from hair. Scherer finds, however, that feathers differ much from the other horny tissues, and especially from hair. Gorup-Besanez found a considerable quantity of silica in feathers.

Physical Properties of Hair.

The hairs are quite elastic. They stretch, without breaking, to nearly one-third more than their original length; and if stretched only one-fifth, they contract again so perfectly that they permanently remain only $\frac{1}{17}$ longer than at first. (*Weber.*) Still, their strength

is great, though so extensible. A hair of the head will support at least six ounces without breaking.

The hairs readily imbibe water, and as readily give it out again; hence they are sometimes dry and brittle, and sometimes moist and soft, according to the amount of moisture the skin or the atmosphere contains. They are also longer or shorter, in proportion as they contain more or less moisture; and hence their use in hygrometry.

The hairs become slowly *colored* during their development; being quite colorless in the embryo, and paler in youth generally than in middle age. In the adult, the palest are the downy hairs which have remained, as it were, in the fœtal condition; while the longer ones are always darker, and the darkest of all are those of the head, beard, and pubes.

The durability of the hair results from its indestructibility by external agents, before alluded to. False hair may be continually worn for many years.

Distribution and Size of the Hairs.

The hairs are distributed over every part of the surface of the human body, except the palm of the hand and the sole of the foot, the dorsum of the last joint of the fingers and toes, the inner surface of the prepuce, the glans penis, the upper eyelids, and the lips. They present differences in size and number in different regions; and also according to age, sex, race, and individual peculiarities.

In size, three varieties may be mentioned (*Kölliker*): 1. Long, soft hairs, 1 to 3 feet and more in length, and $\frac{1}{600}$ to $\frac{1}{240}$ of an inch in thickness; 2. Short, stiff, thick hairs, $\frac{1}{4}$ to $\frac{1}{2}$ of an inch in length, and $\frac{1}{400}$ to $\frac{1}{170}$ of an inch thick; 3. Short and very fine hairs or down (*lanugo*), $\frac{1}{12}$ to $\frac{1}{2}$ of an inch long, and $\frac{1}{2000}$ to $\frac{1}{1200}$ thick. The first includes the hairs of the head, beard, &c.; the second, those of the nostrils (vibrissæ), the eyelashes (cilia), and those in the external auditory passage; the last includes the hairs on the face generally, on the trunk and extremities, on the caruncula lachrymalis, and those (often absent) of the labia minora. (*Henle.*) Other things being equal, black hairs are the coarsest, and blonde the finest.

On the heads of females, the length of the hairs has sometimes equalled that of the whole body, and the coarsest hairs are also found on women. (*Wilson.*) Beards also not seldom reach down to the waist.

The hairs are not true cylinders, as usually supposed, but present

an oval section, or some form differing still more from circular. (Fig. 161, *a*, *b*.) Those of the scalp are the most nearly cylindrical in form.—Nor are they of equal diameter throughout; but fusiform rather, and usually terminating in a very acute point. Indeed, hairs cut off transversely, become pointed again in a short time; apparently by the wearing away of the more external portions of the fibrous substance.

The number of hairs upon a given extent of surface varies with their color and the particular part of the body. On the same extent of surface, Withof found 147 black hairs, 162 brown, and 182 blonde. On a surface one-fourth of an inch square, he found in case of a moderately hairy man, 293 hairs upon the scalp, 39 on the chin, 34 on the pubes, 23 on the forearm, 19 on the outer margin of the back of the hand, and 13 on the anterior surface of the leg. In men, closely set hairs not unfrequently occur on the chest, shoulders, and extremities. At the period of puberty, a sudden development occurs in both sexes upon the pubes and axillæ; and in males on the chin, cheeks, abdomen, and chest also. In a very hairy man, mentioned by Wilson,[1] 52 hairs were found on a certain surface on the chin, and 45 on the pubes. Being married soon after, there were found, at the end of four years, 59 on the chin and 50 on the pubes. On all other parts of the body the hairs were diminished.

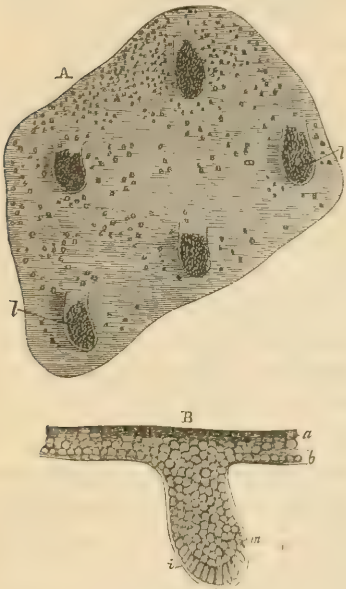
The hairs are implanted either singly or in twos and threes, or even four or five together. The last is the rule in the fœtus, and, so far as the lanugo is concerned, in the adult also. The *direction* of the hairs and hair-sacs, is seldom perpendicular to the skin, but oblique; they being arranged in curved lines which either converge towards certain points or lines, or diverge from them in two or more directions. Hence result a variety of figures, which Eschricht termed "streams, whorls, and crosses;" which are easily made out on the median line of the back, chest, and abdomen, on the line between the thorax and the abdomen, in the axilla, on the scalp, at the internal angle of the eye, and on the elbow. The natural direction of the hairs is, in general, downwards, as shown especially on the various parts of the head. It may, however, here be changed by persevering efforts. Very rarely, two hairs are found implanted in the same hair-sac.

[1] Treatise on the Skin.

Development of the Hairs.

Hairs are first seen in the fœtus, upon the forehead and eyebrows, from the third to the fourth month; the first rudiments of the hair-sacs consisting of flask-shaped solid processes of the Malpighian layer of the epidermis, formed by its growth inwards. (Fig. 166.) The internal cells of these become converted into a delicate hair, surrounded by its internal root-sheath; and the external still remaining soft, constitutes the outer root-sheath and the hair-bulb. Thus the hairs, unlike the teeth, arise at once in their totality. (*Kölliker.*) The first hairs are formed merely of elongated cells similar to the fibrous substance of the later hairs, the medullary cells being entirely absent. The cuticle is, however, clearly visible. The papilla is to be regarded as an outgrowth of the fibrous layer of the hair-sac, analogous to the papillæ of the skin.[1] (*Kölliker.*)

Fig. 166.



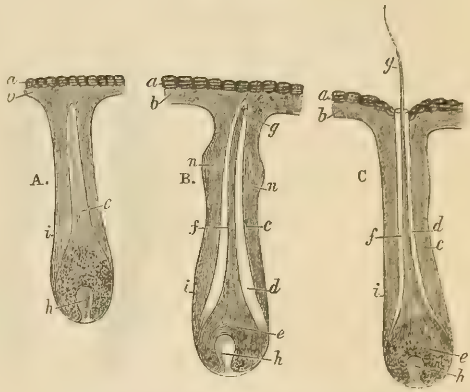
A. Rudiments of hair-sacs *l, l* (fœtus, 16 weeks). B. Single hair-sac seen laterally. *a, b.* Cuticle and stratum Malpighii of the skin. *i.* Basement-membrane of hair-sac prolonged from between the stratum Malpighii and the corium. *m.* Rounded and elongated cells forming the matrix of the hair.

The hairs themselves never appear under from three to five weeks after the rudiments just described, *e. g.* at the nineteenth week, the hairs themselves are nowhere to be seen except on the forehead and eyebrows; and, in the twenty-fourth week, they are

[1] The translators of Kölliker's work (Drs. Busk and Huxley) adopt Reichert's view of the development of the hair, viz., that it results from the cornification of a dermic papilla, and regard a hair as homologous with a tooth, in all its parts. "The substance of the shaft corresponds with the dentine, offering even rudimentary tubes in its aeriferous cavities; the inner layer of the cuticle answers to the enamel, the outer to Nasmyth's membrane, and whoever will compare these structures will be struck by the similarity even in their appearance. The sac answers to the dental capsule; the outer root-sheath to the layer of epithelium (enamel organ) next the capsule; the fenestrated membrane to the stellate tissue, and what Professor Kölliker calls 'Huxley's layer,' to the columnar epithelial layer of the

not yet developed on the hand and foot, and on some parts of the forearm and leg. In some parts, the hairs penetrate the epidermis as soon as formed (on the eyebrows and eyelashes); in others, their points engage obliquely between the proper epidermis and the Malpighian layer, and grow for a time under the former—as on the chest, abdomen, back, and extremities. The *lanugo* is fully developed in the twenty-third to the twenty-fifth week. It gradually acquires a darker color; becoming even almost black on the head, before birth in some cases. A small portion, however, falls off, is swallowed by the fœtus with the liquor amnii, and thus appears in the meconium. Fig. 167 shows the progress of the development of the hairs.

Fig. 167.



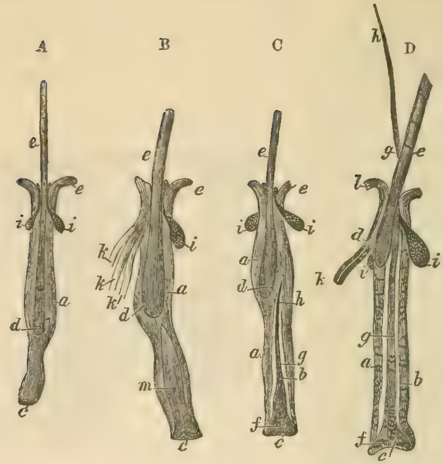
Development of hair (eyebrows). A. First separation of inner and outer portions of the matrix. B. First formation of the hair, the point not yet appearing above the skin. C. Hair seen after its emersion. *a*. Cuticle of skin. *b*. Stratum Malpighii of do. *c*. Outer root-sheath. *d*. Inner root-sheath. *e*. Bulb. *f*. Shaft. *g*. Point of the hair. *h*. Papilla. *i*. Basement-membrane. *n*, *n*. Commencement of the sebaceous glands.

The hairs are shed after birth, new ones forcing out and taking the place of the old ones. The new are formed in processes shooting off from the original hair-sacs. Kölliker discovered and first propounded this law, though it is not yet certain that *all* the hairs fall out, nor at what precise period after birth. The hairs of the head in many children are known to fall out within the first two to six months. The stages of development of the new hairs, as well as the relation of the hairs to the sebaceous follicles already alluded to (p. 227), is shown by Figs. 168 and 135.

The periodical shedding of the hairs of the lower animals is probably secured in the same way; new ones being formed in the old

organon adamantinæ" (p. 190). Without precisely adopting all the analogies just quoted, we admit that a hair is very analogous to a tooth; for we regard a tooth as well as a hair, as being essentially an epidermic (epithelial) production. The manner in which the hairs fall out, and are succeeded by others, shows (as well as their development), that they are the analogues of the teeth on the one hand, and of the epidermis on the other.

Fig. 168.



Development of second eyelashes (infant, one year old). A. Formation of matrix of second hair. B. Incipient development of the young hair. C. The same more advanced and pushing up the old hair. D. The young hair emerging from the opening, and the old one about to fall out. *a*. External root-sheath. *b*. Internal do. of young hair. *c*. Cavity for the formation of papilla. *d*. Bulb of old hair. *e*. Its shaft. *f*. Bulb of young hair. *g*. Its shaft. *h*. Its point. *i*, *i*. Sebaceous glands. *k*, *k*. Sweat ducts. *l*. Passage of external root-sheath into the stratum Malpighii of the skin. *m*. First appearance of young hair.

sacs, and thus displacing the first hairs, after cutting off their supply of nourishment. The striking analogy in these particulars of the hairs to the teeth, will become apparent when we come to speak of the development of the latter.

Before the old hair falls out, it becomes entirely horny in consistence, and its bulb is no longer soft and cellular, but solid and fibrous like the shaft, with a clavate enlargement. (Fig. 169.)

This condition marks the end of development and of growth; and all hairs which fall out present it.

Fig. 169.

Old hair falling out. A, shows a diminished activity of growth by the small amount of pigment in the cells of the pulp, and the interrupted line of dark medullary substance. At B, provision is made for the formation of a new hair, a new pulp appearing in connection with the old one. At C, the hair has died and fallen out, deprived of its sheath and of the cells composing the pulp of a living hair.

And since it is certain that in full health, the hairs are constantly falling out, doubtless the formation of new ones, as just described, is also simultaneously taking place. Hence not unfrequently, two hairs are seen coming out of the same aperture, as before stated—the old and the new one. When a hair is *pulled out*, however, it breaks off just above the bulb, and another is produced from the latter directly, as at first. Heusinger found that on pulling out the whiskers of dogs, they were reproduced in a few days from the old sacs. And when the hairs fall out after sickness, it is probable that they are reproduced from the old sacs, since the latter remain for a long time. (*E. H. Weber.*)

Uses and Physiological Relations of the Hair.

The uses of the hair are various, depending partly upon its physical and partly on other characteristics.

1. The hair is for protection, whether against cold, or other agents, as on the head, &c.; against exposure to light, as in case of the eyebrows.

2. It is for concealment, as on the pubes, &c.

3. It prevents the ingress of foreign bodies into the passages opening externally; as the vibrissæ of the nostrils, the cilia of the eyelids, and the hairs sometimes existing in the external meatus auditorius.

4. The hair gives character and expression, as the beard; which is also protective against changes of temperature in circumstances requiring its agency in this respect. A tendency to affections of the bronchial mucous membrane is, therefore, frequently removed by allowing the beard to grow.

5. The hair is for ornament, as that of the head.

The hairs, like the nails, grow again if cut or worn away; otherwise they remain at their typical length in the various parts of the body. Berthold found the hairs of the heads of females from 16 to 24 years old, grew about 7 lines a month. If the beard were shaved every 12 hours, it would grow to from $5\frac{1}{2}$ to 12 inches, and if every 24 hours, to from 5 to $7\frac{1}{2}$ inches, *per annum.* Shaving once in 36 hours would reduce the annual growth to from 4 to $6\frac{1}{2}$ inches. The beard grows $\frac{1}{6}$ faster by day than during the night; and in 18 days, about $\frac{1}{40}$ more in summer than in winter. Kölliker supposes that each sac is supplied by the vessels of the papilla with a sufficiency of nourishment to develop the hair to its typical

length, and to keep the whole hair in a state of moisture and vitality; and that if the hair be cut, the then superfluous amount of nourishment develops the hair till it again attains to the previous length. This is equivalent to saying that the hair-sacs have, each, the power to develop a hair of a determinate length, it being also the function of each to maintain this length; so that if the hair is cut, it again attains to it. Kölliker states that cut hairs do not produce new points, while others have asserted the contrary. Whenever they become pointed again after being cut, as is quite certain in many cases, it is doubtless from mere mechanical causes already suggested, and not from developmental agencies. The growth takes place in the hair-sac, and at the root; the shaft being thus constantly protruded, till the hair attains its normal length.

Though the hairs are not vascular they are not a dead substance. Fluids are, doubtless, effused through them which serve for the maintenance of their vitality, ascending from the bulb through the fibrous portion and the medulla to every part, probably by mere imbibition. After accomplishing their object, they pass off by evaporation, and another supply is afforded. From without, the hair can absorb fluids only in the form of vapor. The oily matter of the sebaceous follicles is spread upon the cuticle of the hair, but does not, probably, penetrate it at all; nor is there any greasy fluid afforded within by the medullary cells.

The existence of air-vesicles in the medullary axis, can arise only from a diminished supply of the fluids from the sac, compared with the amount evaporated. It is thus due to a partial drying up of the hair. The fibrous portion appears to be the most actively nourished, and is the most rich in fluids, though comparatively so hard. Gray hairs contain more of the air-vesicles, and to them its silvery appearance is due. That their vitality is not, however, essentially diminished, is proved from the fact that they grow rapidly when cut.

Thus the hairs live, and must, of course, be modified in their development and growth by the vital conditions of the skin. The condition of the hair is, therefore, an index of that of the skin. If they are soft and shining, it may be inferred that the skin is turgescent and active; if dry and harsh, that it is in a collapsed and inactive condition.

Any essential modification, therefore, in the circulation of the skin, and hence of the blood supplying the hair-sacs, modifies the

condition of the hair. Thus it may fall out after sickness, especially from fevers. In old persons, also, it falls out, probably from an obliteration of the vessels of the hair-sacs.

The process of whitening of the hairs (gray hairs) is very obscure. Its immediate cause is chiefly a decoloration of the fibrous portion of the hairs, and an increase of the air-vesicles; but how this is produced is not understood. Intellectual activity, grief, nervous influences, and old age, are certainly concerned in it. The rapidity with which this change may be effected, also testifies to the vitality of the hair; cases having occurred in which it has become gray within a few hours, under the influence of violent emotions.[1]

Dzondi and others have succeeded in transplanting hairs with their sacs.

The fact that the hairs of the head may become erect under the influence of powerful emotions, is usually associated with the *cutis anserina*, so called. We should, however, associate it with the fact established by Eylandt, that the hair-sacs of various parts of the body have smooth muscular fibres inserted into them, and which he has termed the *arrectores pili*.

The presence of sulphur in hair accounts for the peculiar odor evolved by its combustion. The various hair-dyes also act by combining with it, and producing a sulphuret of the metal they respectively contain, as silver, manganese, &c. The nitrate of silver is most frequently used (p. 257).

Pathological States and Developments of the Hair.

There may be an excessive growth or a falling out of the hairs. They may also be developed in abnormal directions, as is often seen on the head. They may be found abnormally, on even mucous surfaces. Hairs have been developed in the intestines, the gall-bladder, in ovarian cysts, in steatomatous and encysted tumors, and in the lungs even. (*Mohr's case.*) They are often largely developed on moles and nævi. In all these cases they possess sacs and root-sheaths, and in all respects a normal structure. Indeed, since they

[1] A Captain P., of Vermont, was captured by a party of British soldiers in 1813 on the Canadian frontier, and put under guard in the evening, with the assurance that he would be shot the next morning. When the appointed time had arrived his hair had entirely changed from a jet black to gray.

Dr. J. W. Richards, of New York city, mentioned to the author a man whose hair changed from a jet black to gray and *back again three times* in the course of ten years. No cause could be assigned. He was in perfect health, and not of an excitable temperament, and the change began at the age of thirty-five years.

are an epithelial production, we should not be unprepared to find them wherever an epithelium exists, though they have not been found on the serous membranes.

No hairs are developed upon cicatrices on the skin.

The falling out of the hair of the head, constitutes baldness (alopecia). When due to an atrophy of the hair-sacs, remedies are, of course, of no avail. One cause of its far greater frequency in men than in women, is, very probably, the style of hat so generally worn, especially in this country; and which by its stiffness, its form, and its heating powers, at the same time banishes all comfort, and violates the principles of good taste, common sense, and physiological science.

Some diseases of the hair are produced by vegetable parasites (fungi) in the interior of the hair itself. This is the case with herpes (or tinea) tonsurans (*Gruby*); and Dr. Jenner, of London, has shown that the sulphurous acid destroys the parasite and cures the four varieties of this disease.[1] In porrigo decalvans (*Willan*), the fungus is under and around the cuticle of the hair. (*Gruby.*)

In plica Polonica, in which the hair becomes matted together, and appears even sensitive, a fungus is developed, according to Guensberg and Walther, in the bulb and shaft of the hairs, and partly destroys them. Munter, however, found no such fungus.

CHAPTER II.

YELLOW FIBROUS TISSUE.

The yellow fibrous tissue (elastic tissue), presents three varieties of form:—

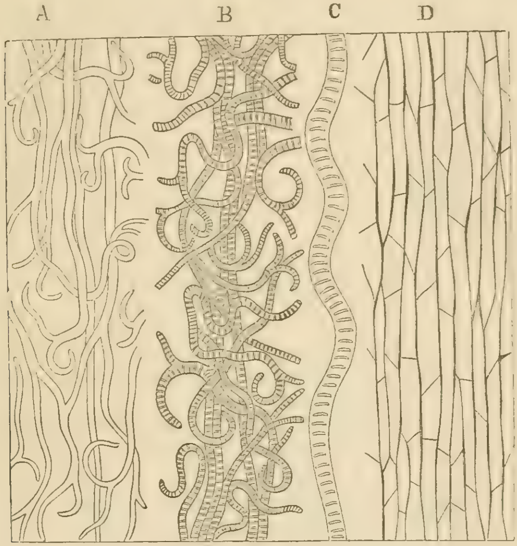
1. The most common form consists of solid fibres of a yellowish color, bifurcating or even trifurcating, and anastomosing very freely; curled or coiled up at their extremities, and sometimes being coiled around other tissues. These fibres vary from $\frac{1}{21000}$ to $\frac{1}{4000}$ of an inch in diameter, and are often studded with nuclei. More or less of them are always found in connection with the white fibrous tissue. (Fig. 170, A.)

2. Another form found by Queckett in the ligamentum nuchæ of the giraffe, consists of similar coiling and bifurcating fibres, each

[1] Tinea favosa, tonsurans, decalvans, and sycosa. See *Am. Med. Monthly*, March, 1854, p. 240.

being marked with transverse striæ, not extending quite across them, but being principally confined to the centre of each. Kölliker asserts that this appearance is due to the formation of little cavities within the fibres. (Fig. 170, B.)

Fig. 170.



A. Yellow elastic fibres from the ligamentum nuchæ of a sheep. B. Yellow fibres from the ligamentum nuchæ of the giraffe. C. One of the same, magnified 500 diameters. D. Vessels of the ligamentum nuchæ of a young calf. (*Queckett.*)

3. The third variety consists of flat, rather broad, somewhat brittle, and much ramifying bands (Fig. 171), often so arranged as to form a network (or in the form of the finest, straight threads (Fig. 172), as in the peritoneum of some young animals), as found in the middle coat of arteries.—The elastic fibres studded with nuclei have been called *nuclear fibres.* But all may have been so at first; at least the largest were originally as small as those. (Fig. 173).

Elastic fibres cannot be isolated for examination by mere mechanical means, since they never occur independently of other histological elements. They always appear where the white fibrous tissue exists, and are often blended, as in the middle coat of arteries, with the smooth muscular fibres. The last two elements may, however, be removed by boiling with acetic acid, and then adding a dilute solution of potash, when the isolated elastic fibres remain.

The elastic fibres are *arranged* in three principal forms in the various organs: 1, wide-meshed or intricately formed nets with hook-like indentations, and forming considerable masses; 2, as

Fig. 171.

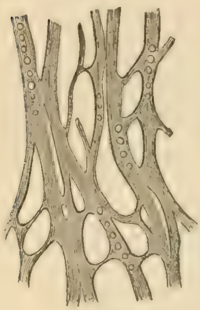


Fig. 172.

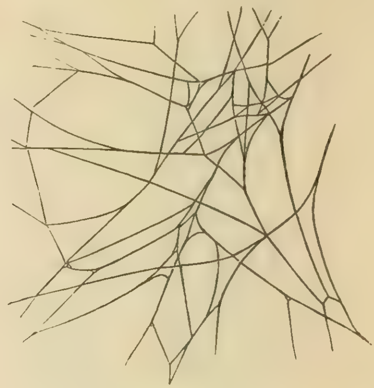


Fig. 171. Elastic network from the tunica media of the pulmonary artery of a horse, with cavities in the fibres.—Magnified 350 diameters. (*Kölliker.*)

Fig. 172. Yellow fibrous element of the areolar tissue of serous membrane, from the mesentery of the rabbit, treated with acetic acid. (Magnified 300 diameters.)

bundles of fibres nearly parallel (as in certain ligaments), or twining around other tissues in a spiral manner; 3, forming a fenestrated membrane with tolerably large intervals, as in the arteries.

When the yellow elastic fibres form masses, as in the ligamentum nuchæ, &c., no nerves or lymphatics are found among them. The vessels, comparatively few in number, lie between the fibres and parallel to them, much like those of tendon. (Fig. 170, D.) The connecting branches, however, are not transverse, but pass off at angles of about 40°; so that the spaces inclosed by the vessels have a somewhat rhomboidal outline.

Chemical Composition of Elastic Tissue.

The investigations of chemists have not yet led to any very accurate knowledge of the composition of this tissue, and its general chemical relations.

Cold acetic acid does not act upon it; and therefore displays it when blended with white fibrous tissue, by dissolving the latter, and thus isolating the former. Mulder and Dundas found the fibres entirely unchanged after boiling forty hours, and obtained no gela-

tinous substance from them. Scherer states that elastic tissue is proteine plus two equivalents of water (Pro+2HO). Robin and Verdeil have, however, found in it a peculiar immediate principle, which they have called elasticine (p. 100).

Elastic tissue is unaffected by all the weaker acids, and is not dissolved by the gastric fluid. It resists decomposition longer than any other soft and moist tissue. Its ash constitutes 17 per cent. of it.

Properties and Uses of Elastic Tissue.

The yellow fibrous tissue manifests no vital properties, except so far as to secure and maintain its own development. As a constituent part of the organism, it manifests only *physical* properties; of which its extensibility and elasticity are the peculiar and essential ones. It is, however, also flexible, and considerably strong. Mr. Queckett found that the ligamentum nuchæ of a giraffe, 6 feet and 2 inches in length during life, contracted at once, on being removed, to 4 feet; and that an immense force was required to stretch it again to 5 feet.[1] The elasticity of this tissue is preserved for almost an unlimited period; it being revived by the application of water after the fibres have been long kept in a dried state.

Uses.—The yellow fibrous tissue is useful by reason especially of its extensibility and elasticity. Whenever a tissue is required possessing these properties, as in extensible ligaments (the ligamentum nuchæ, chordæ vocales, &c.) and in the bloodvessels, this is the one found. Its properties, indeed, are very similar to those of gum-elastic, except that it is much stronger. Its use in each particular part or organ will at once be inferred, therefore, from the following account of its distribution in the various organs of the human body.

Distribution of the Yellow Fibrous Tissue.

The yellow elastic tissue forms the greater portion of the following structures: the ligamentum nuchæ, the ligamenta subflava, the crico-thyroid and the thyro-hyoid membranes, the thyro-arytenoid ligaments (chordæ vocales), the stylo-hyoid ligament (*Hassall*), the longitudinal bands of the trachea and bronchi, the internal lateral ligament of the lower jaw, and the ligamentum suspensorium penis. It is also found at the base of the epiglottis, and the fascia transversalis is composed in great part of it. It combines with the white

[1] The weight of the entire ligament was more than 8 pounds.

fibrous tissue to form the areolar tissue, wherever found; and of the third form of it the middle coat of the large arteries is almost exclusively, and that of the smallest in part, formed. It also abounds between the air-cells of the lungs.

None of the preceding structures are, however, formed of the elastic tissue alone. *E. g.* between the yellow fibres of the ligamenta subflava, "*which are not collected into either fasciculi or lamellæ,* but are continuously connected throughout the entire thickness of each yellow ligament, there is interposed some white fibrous tissue; upon the whole in small quantity, but demonstrable in every preparation, and occurring in the form of lax, undulating fasciculi, which are arranged parallel with the principal direction of the elastic fibres." (*Kölliker*, p. 284.)

Distribution of the Elastic Tissue in the Lower Animals.

In all the vertebrated classes this tissue is found in the same localities as in man, and in some places besides—as in the ligaments of the cat's claw, and in the alary membrane of the mammals.

In large animals, as the elephant and rhinoceros, the yellow fibrous tissue is employed in the form of a belt to support the abdominal parietes. (*Queckett.*) In the ligamentum nuchæ of the giraffe, before alluded to, the fibres are marked with transverse striæ, extending through about the central third of their width. The internal portions were, however, made up entirely of the common plain fibres. Similar striated fibres also are found in the rhinoceros, and the sheep; and even in arteries.

A variety of this tissue constitutes the ligament supporting the expanded wings of the larger birds, as the eagle, crane, heron, &c. It also exists in the lungs of birds.

It is a ligament of elastic tissue which in the bivalve mollusca keeps the valves open whenever the adductor muscle ceases to close them by its contraction. In the *oyster* this tissue is placed *within* the hinges, and therefore is compressed whenever the valve is closed. Hence the compressed elastic tissue forces the valves apart when the muscle ceases to keep them closed. In the *cockle* the elastic tissue is placed externally to the hinge, and being stretched when the valves are closed, pulls them open by its elasticity whenever the adductor muscle ceases to act.

The form of this tissue occurring in the middle coat of arteries, was found in that of the aorta of a whale to be $1\frac{1}{2}$ inch thick; the diameter of the vessel being 12 inches, and its length over 50 feet.

Development of Elastic Tissue.

The supposition of Schwann, that this tissue is developed from

cells, receives increasing support from recent investigations. These are peculiarly fusiform or stellate, sharply-pointed cells, producing long fibres or reticulations by their coalescence. The nuclei sometimes remain in the elongated or fibriform cells, and thus the latter have been termed *nucleus fibres.* (*Gerber.*) In other cases all traces of the nuclei disappear, and perfectly homogeneous fibres or networks are produced. These may remain fine through life as at first, or become coarse by increase in thickness. When once perfectly developed, the fibres undergo very little change; though so long as the nuclei or other indications of the original cells still appear, a certain amount of metamorphosis and repair may take place (p. 269).

It is the development of the *nuclear fibres* almost alone that has been accurately examined; and Kölliker has demonstrated that they are formed from fusiform cells, $\frac{1}{1200}$ to $\frac{1}{800}$ of an inch in length, which first appear in the fœtus of from two to three months (Fig. 173), the fibres of the white fibrous tissue being already well formed. In the fœtus, at birth, the cells have so elongated, and coalesced into a network, that they can no longer be isolated as before.

What is asserted of the nuclear fibres also holds good of the larger elastic fibres; for there is reason to believe that all these have at one time been nuclear fibres. In fact, there is not a single true elastic fibre in the new-born child; since even those of the ligamentum nuchæ, &c., when largest, are not more than $\frac{1}{15000}$ to $\frac{1}{12000}$ of an inch in diameter (Fig. 174), and from these, doubtless, the coarse fibres are subsequently developed. In some places, even in the adult, the original condition of a system of canals (tubular cells) is still to

Fig. 173.

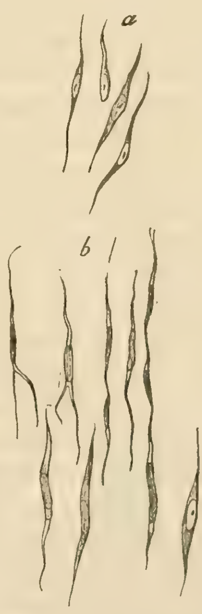


Fig. 174.

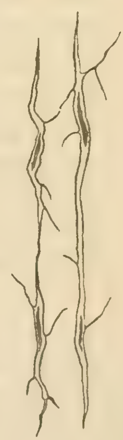


Fig. 173. Formative cells of the elastic fibres from the tendo-Achillis. *a.* Of a four months' embryo. *b.* From a seven months' fœtus; a few cells free, with one and two processes, others united by twos and threes. (Mag'd 350 diams.)

Fig. 174. Stellate formative cells of the nuclear fibres out of the tendo-Achillis of a new-born infant.—Magnified 350 diam'rs. (*Kölliker.*)

some extent retained. But it by no means follows, as Virchow asserts, that all the nuclear fibres are hollow tubes for the nutrition of the white fibrous tissue blended with the elastic. On the contrary, Kölliker maintains that all fine elastic fibres, which no longer present any traces of the original cell, are *solid*, and are useful only so far as they are elastic—as those of the areolar tissue, of the corium of the skin and serous and mucous membranes, of the fasciæ, the perimysia, the periostea, the dura mater, and the walls of vessels. For the cornea alone, where the elastic tissue remains in quite an embryonic condition, does he adopt Virchow's hypothesis. In any instance or any part where the elastic tissue is still undeveloped, this may be the case also; but, if so, this result is secondary and incidental, and not the definite object of the tissue under consideration, as Virchow maintains. Donders maintains that all *cell-membranes* consist of a substance identical with, or at all events very similar to, elastic tissue. This opinion rests, on the one hand, on the supposed development of elastic tissue, and especially of nuclear fibres, from the walls of cells; and, on the other, on the circumstance that certain membranes and textural elements, which in their physical and chemical properties closely approximate to elastic tissue (*e. g.* nerve-sheaths), may be found to be formed from cell-membranes. (*Lehmann.*) We cannot, however, accept this view in its general application; for the walls of very young cells, of cytoid corpuscles and blood-cells, and the cells of the deepest layers of compound epithelia, are readily soluble in acetic acid and in very dilute alkalies.

If the elastic tissue is removed or destroyed, it is *not regenerated;* but an imperfect areolar tissue takes its place. Pathological new formations of it are, however, not rare.

The *growth* of the yellow fibrous tissue is secured by an increase in size of each fibre, as well as by the formation of new ones, doubtless. Kölliker found that the fibres in the ligamentum nuchæ of the calf are considerably finer than those of the ox; and that in the new-born child not a single true elastic (coarse) fibre exists, but only the nuclear (fine) fibres.

Pathological New Formations of Elastic Tissue.

Fibres of this tissue often occur in pathological epigeneses, in great numbers and in considerable masses; the contiguous fibres being also interwoven into a close and fine lattice-work, presenting the same morphological conditions as coagulated (fibrillated) *fibrine*, and

for which the finer fibres may be mistaken. They are, however, at once distinguished by their unchangeableness under the action of acetic acid and dilute solutions of the alkaline carbonates.

CHAPTER III.

WHITE FIBROUS (COLLAGENOUS) TISSUE.

MUCH confusion has resulted from the blending together by authors, in their descriptions, of the white and the yellow fibrous tissues, under the name of *connective tissue.* Kölliker includes under the latter designation the white fibrous tissue on the one hand, and on the other, as mixed with it, elastic fibres, fat-cells, cartilage-cells, and pigment-cells of different kinds. Lehmann regards connective tissue and areolar tissue as being the same, and both as being identical with the white fibrous tissue; the areolar tissue being its amorphous (or loose—*Kölliker*), and the connective tissue the formed or solid variety.

True *connective* tissue, or that which connects together different parts and organs, is almost invariably found to consist of two or more distinct tissues interwoven, of which the white fibrous tissue is usually merely the most abundant. White fibrous tissue alone, therefore, cannot properly be termed connective tissue, any more than the yellow fibrous which is almost always blended with it.

We shall therefore adhere to both fact and simplicity if we describe the white fibrous tissue under this name as a simple tissue; and speak of its union with the yellow fibrous tissue in the *areolar* tissue (and which is usually the connective tissue) further on.

Fig. 175.

White fibrous tissue from ligament (Magnified 65 diameters.)

The white fibrous tissue is so named from its appearing under the microscope to consist of very fine fibres (Fig. 175), $\frac{1}{40000}$ to $\frac{1}{24000}$ of an inch in diameter, a pale color, homogeneous appearance, and non-striated. (*Kölliker.*) These ap-

parent fibres are united by a clear connecting gelatinous substance (homogeneous substance), and fasciculi are thus formed, averaging $\frac{1}{3000}$ to $\frac{1}{2400}$ of an inch in diameter. These bundles somewhat resemble the striated muscular fibres, but have no actual striæ, or external investments at all comparable to the myolemma, and are smaller. They are arranged, like long, wavy cords, so as to form large lamellæ and bundles (as in ligaments); or they coalesce, like the elastic tissue, into networks and meshes. In rare cases the bundles appear to be homogeneous, and not composed of fibres, as in the perineurium (Remak's fibres). In some cases, indeed, neither bundles nor fibres can be made out; and this has been called *homogeneous* (or Reichert's) *connective tissue.* This may be regarded as either white fibrous or areolar tissue, in an undeveloped state.

Todd and Bowman—and, since, Reichert and Dr. Paulsen—maintain that the fibrillation of this tissue is merely apparent; it being really, in its normal state, a homogeneous mass, marked by longitudinal parallel streaks, having at times a tendency to split up "*ad infinitum*," and splitting into membranes rather than fibrous fragments. Though we agree with the writers just quoted, the fibrillated *appearance* justifies the name we still prefer for this tissue; and it at once occurs that if no minute fibres exist, like those described by Kölliker, then the bundles, so called, become fibres of larger dimensions. For every histological purpose, therefore, the term white fibrous tissue is to be preferred.

No nerves or lymphatic vessels are supplied to this tissue. The manner in which vessels are distributed to parts composed of it, will be shown further on (Fig. 176).

Chemical Composition of White Fibrous Tissue.

This tissue is about 63 per cent. water, and, like bone and the teeth, affords gelatine to boiling water. It has hence been termed one of the *gelatinous* tissues. That the gelatine does not, however, pre-exist in these three tissues, but is formed by decomposition of another substance, has already been shown (p. 98). The substance thus converted into gelatine is called osteine, and is the same in bone, teeth, and white fibrous tissue. The apparent fibres, before mentioned, swell up and assume a viscid, hyaline appearance in alkalies, and cannot be again brought into view by the addition of water. The same result follows if a solution of caustic potash of

10 per cent. be used, and the transparent mass may be torn with equal ease in any direction. If, however, the potash be now removed by acetic acid, the original texture returns. (*Paulsen.*) While acetic acid obscures the parallel lines, and renders the mass transparent, it usually brings into view broken, elongated corpuscles, the remains of the developmental cells. (*Kölliker.*) The addition of a mineral acid brings the lines into view again.

It is the white fibrous tissue which some histologists have termed the collagenous element of the areolar tissue, and the *fibrillated collagenous*[1] *substance.* It will be frequently termed the "collagenous tissue" and the "collagenous element," in the subsequent portions of this work.

Properties and Uses of White Fibrous Tissue.

White fibrous tissue, like the yellow fibrous, manifests no vital properties (save the power of securing and maintaining its development), but *physical* properties merely, viz: great strength, great flexibility, and almost total inextensibility. It may, however, be somewhat extended by a slowly-acting and long-continued force.

The strongest cords used in the arts are made of this tissue—as musical strings, &c. Mascagni calculated that the human tendo-Achillis will sustain a weight of 1,000 pounds.

Its flexibility is owing to the water it contains. When dried, it becomes quite rigid. In this state, also, it completely resists the putrefactive process.

Uses.—In all cases where a tissue, strong, flexible, and totally inextensible, is needed, this is the one found. Ligaments and tendons are composed almost exclusively of it. Its uses in particular parts and organs vary, as seen in the following paragraphs. Sometimes it is merely protective of the softer parts it incloses; as in case of the sclerotica, the tunica albuginea testis, &c.

Distribution of the White Fibrous Tissue.

1. White fibrous tissue constitutes the greater portion of tendons, aponeuroses, and articular ligaments. It also constitutes a large portion of the fibrous membranes, so called—viz., the periosteum, perichondrium, and dura mater—and enters with the yellow fibrous into the formation of the areolar tissue. Hence it forms the greater

[1] From κόλλα, glue, gelatine, and γένος; gelatine-producing; synonymous with *gelatigenous.*

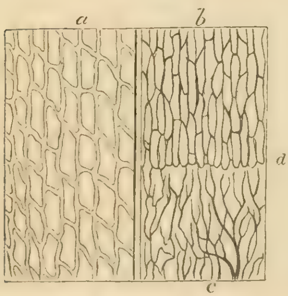
part of the corium of the skin, and of serous and mucous membranes; and of the vascular membranes, so called, as the pia mater and the plexus choroides.

2. It also forms the white, dense tunics of many soft organs; as the perineurium, the sclerotica and cornea, the fibrous coat of the spleen and kidneys, and the fibrous tunic of the testis, ovaries, penis, and clitoris.

In all the preceding structures the yellow fibrous tissue is found in combination with the white. The arrangement of the latter, in all except the true membranes, will be disposed of here.

1. *Structure of tendons and ligaments.* These consist of parallel bundles of white fibrous tissue, united by loose areolar tissue into large cords. Between these the vessels ramify, and a relatively very small number of elastic fibres, or of networks formed of them. Fig. 261 shows a transverse section of a tendon. The latter and the ligaments have no nerves or lymphatics. The vessels of a tendon of an ostrich are shown by Fig. 176. The manner of union between tendon and muscle, and further particulars in regard to the tendons, will be explained in the chapter on "Striated Muscular Tissue."

Fig. 176.



a. Vessels of the tendon of an ostrich. *b, c.* Vessels of muscle and tendon, uniting at *d.* (*Queckett.*)

2. *Aponeuroses* are composed of fasciculi of white fibrous tissue, so interwoven as to form a membraniform expansion of varying thickness. If very thin, no vessels are sent among the fasciculi, but only to the areolar sheath in contact with each surface. If thick, the vessels penetrate between the fasciculi in an irregular manner. Aponeuroses are found at the origins of muscles, as the tendons constitute their insertion. They also exist distinctly from muscles, as in the case of the deep fascia of the extremities (femoral and brachial aponeurosis, &c.).

3. *Fibro-cartilages* have the same structure as tendons and ligaments, except that cartilage-cells are scattered among the bundles of white fibrous tissue, and that they contain no finer elastic fibres. Fig. 202 represents a section of fibro-cartilage. They exist as special organs (interarticular fibro-cartilages and the cotyloid liga-

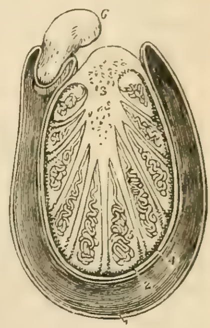
ments), or are found developed in the tendons, tendinous sheaths, and the ligaments.

4. The *fibrous membranes*, so called, differ from the tendons only by the frequent interweaving of the bundles, to give them their difference in form, and by the greater amount of elastic fibres. Under this head may be mentioned—

First. The *deep fasciæ* (femoral, &c.), which very nearly resemble the aponeuroses in structure, and some of which are classed with them.

Secondly. The *periosteum* and *perichondrium*, which sometimes contain a great number of elastic fibres, are more vascular than the preceding, and are sparingly supplied with nerves and lymphatics. The dura mater also belongs here, it being the internal periosteum (endosteum) of the cranium, while it at the same time protects the encephalon.

Fig. 177.



Section of testis. 1. Cavity of tunica vaginalis. 2. Tunica albuginea. 3. Mediastinum testis, giving off the trabeculæ; between which are the lobules (5) of seminiferous tubes. 4. Pia mater testis. 6. Epididymis, and below it the corpus Highmorianum, above 3.

5. The *white*, *dense tunics* included under the second head, except the cornea—viz: the fibrous tunic of the testes and ovaries, penis and clitoris, and the fibrous envelop of the spleen and kidneys—consist of solid white fibrous tissue, with elastic fibres interwoven. In the case of these organs, also, the fibrous layer projects into the interior, where, mixed to a greater or less extent with smooth muscular fibres, it constitutes dissepiments or a kind of framework, or forms a stroma or a trabecular network. The object here is to inclose and protect the parenchyma of the organs in question. The sclerotica, however, has no such internal projections; and the perineurium is homogeneous in structure, as has been already stated (p. 276). Fig. 177 shows the fibrous trabeculæ in the testis, radiating from the mediastinum.

6. The so-called *vascular membranes*—the pia mater, choroid plexus, the choroid coat of the eye, and the iris—all have numerous vessels; for the nutrition, however, especially of other parts. They vary in structure. The iris and the pia mater have parallel, matted, and anastomosing bundles of white fibres, without any elastic tissue. The choroid plexus and the choroid membrane of the eye,

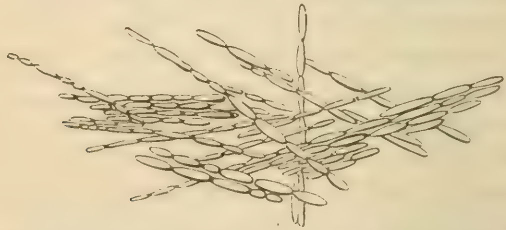
have a homogeneous tissue like the perineurium, to which the peculiar anastomosing pigment-cells, described on page 133, are added.

7. *Structure of the cornea.*—The true cornea is to be included histologically under white fibrous tissue; though in chemical composition it is allied to cartilage, since it affords chondrine, and not gelatine on boiling.

The cornea considered as a whole, consists of five layers: 1, the *true lamellated cornea;* 2, 3, the anterior and posterior elastic layers, and 4, 5, the anterior (external), and posterior (internal) epithelium. The anterior epithelium consists of three or four strata of cells, and the posterior of one. The anterior and the posterior elastic layers are merely basement-membranes underlying the epithelia. The posterior is called the "membrane of Demours." The anterior is bound to the lamellated cornea by fine elastic fibres, while the posterior is not. The former is probably what remains of the vascular conjunctiva covering the cornea of the fœtus.

But the *true cornea* (lamellated cornea, *Todd and Bowman*), constitutes the greater part of the substance of this organ. This consists of about sixty superimposed lamellæ, composed of transparent fibres interwoven so as to leave tubular spaces[1] between them, and is continuous with the white fibrous tissue of the sclerotica. These tubular interspaces are arranged with tolerable regularity and constricted at intervals, as shown by Fig. 178. This lamellated tissue is the only portion of the cornea which is continuous with the

Fig. 178.



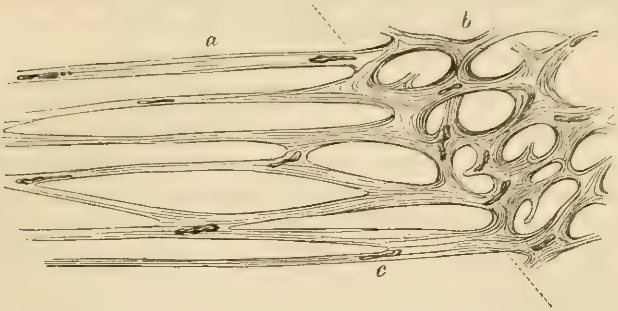
Tubes of the cornea proper, as shown in the eye of the ox, by mercurial injection. Slightly magnified.

sclerotica, and its fibres appear similar to those of the latter, except that they are transparent (*Todd and Bowman*). Their continuity is

[1] Kölliker, however, believes these tubes are artificial dilatations by injection between the transparent fibres.

shown by Fig. 179. The tubular interspaces are doubtless filled with a transparent fluid. No vessels extend into the substance of

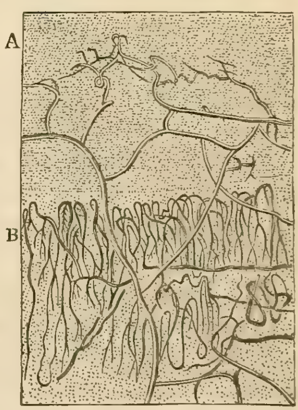
Fig. 179.



Vertical section of the sclerotic and cornea, showing the continuity of their tissue between the dotted lines. *a.* Cornea. *b.* Sclerotica. In the cornea, the tubular spaces are seen cut through, and in the sclerotic the irregular areolæ. Cell-nuclei, as at *c*, are seen scattered throughout, rendered more distinct by acetic acid. (Magnified 320 diameters.)

the cornea. Those of the sclerotica form loops extending to its margin, as shown by Fig. 180. Some superficial branches belonging to the conjunctiva extend, however, in front of the cornea to the distance of $\frac{1}{8}$ to $\frac{1}{2}$ of a line from its margin, as seen in the figure. It is suggested by Kölliker that vessels carrying the liquor sanguinis alone, may communicate with these, and extend throughout the cornea.

Fig. 180.



Nutrient vessels of the cornea. A. Superficial vessels belonging to the conjunctival membrane, and continued over the margin of the cornea. B. Vessels of the sclerotic returning at the margin of the cornea.

That the fluid in the tubular interspaces is the blood-plasma, may be inferred from the fact that though there are no vessels in the cornea, incised wounds heal very readily. This is the case usually after the removal of cataract by extraction. Since the plasma must, however, be afforded by the perimetral vessels, it is important not to carry the incision further round than is actually necessary.

In diseased conditions of the cornea, however, the deep-seated vessels may be prolonged into its entire substance, while the super-

ficial form a dark band of considerable breadth around its margin. Opacity very frequently results from the organization of plasma in the tubular interspaces, and between the laminæ; the new formation not being transparent like the original tissue.

The *arcus senilis*, occurring mostly in aged persons, results from a fatty degeneration of the cornea.

Distribution of White Fibrous Tissue in the Lower Animals.

This tissue is found in all vertebrate animals in about the same conditions as in man; while in the invertebrata it is very rare. In mollusca the tendinous fibres are very large; in the terebratula, even $\frac{1}{500}$ of an inch in diameter, and collected into strong bundles presenting a beautiful silvery aspect. In birds, the tendons of the legs are very large, and more or less ossified. Every one has noticed this, especially in the case of the turkey, goose, and other species most frequently used as food. The analogy of this tissue to bone, in a chemical point of view, has already been suggested (p. 276), and will account for its tendency to ossification.

Development of White Fibrous Tissue.

Donders and Virchow coincide in the opinion that the true white fibrous tissue (the gelatinous intercellular tissue of white fibrous tissue, bones, and teeth), does not originate from cells, but is directly separated from a plastic fluid; while the other elements—lacunæ and pores, cartilage-cells, and nuclear (elastic) fibres—are primarily formed from cells. Kölliker thinks differently as to the development of the fibres of white fibrous tissue; asserting that the nuclear fibres are developed not from the nuclei of the cells of the white fibrous tissue of the embryo, but from the cell-walls; while the cell-contents are converted into the collagenous element, or white fibrous tissue.

We agree with Reichert and Virchow that the elastic fibres blended with the collagenous element, or true white fibrous tissue, represent the *cells* of cartilage; while the white fibrous tissue represents the *matrix* or homogeneous substance of cartilage; and, like the latter, is not developed from cells. This view is confirmed by an examination of the insertion of tendons into bones in young animals, and in which the surface of the latter is still in a state of cartilage.

The white fibrous tissue alone has been confounded with the areolar, under the name of the connective tissue. Kölliker's "areolated connective tissue" is the true areolar tissue, and will be de-

scribed in the following chapter. Cells appear to perform an important part in the development of the latter tissue, as will be seen. But, for the present, we may adopt the view which regards the elastic fibres as developed from cells, while the collagenous element, or white fibrous tissue, is at first formed directly from the plasma.

The *growth* of white fibrous tissue is secured by a gradual increase of the bundles before described; and this occurs probably from the plasma directly—each fasciculus assimilating to itself the amount required.

The *reparation* of this tissue, if inflammation occurs, is imperfect; *e. g.* if a portion of a tendon be removed, or if the ends of a divided tendon be separated (as in operations for club-foot), the new tissue is similar to white fibrous tissue; but is developed from cells, and is a condensed form of areolar tissue, rather. If inflammation does not occur, the exuded plasma is directly (*i. e.* without the intermediation of cells), converted into a collagenous tissue precisely identical with the original development.

Pathological States and New Formations of the White Fibrous Tissue.

1. It is difficult to distinguish between a new formation and a hypertrophy of the white fibrous tissue, if the change occurs in a part or organ in which this tissue naturally exists. A hypertrophy, so called, of the capsule of Glisson produces the granular liver, or *cirrhosis;* and hypertrophy of the collagenous tissue between the tubes in the kidney, produces the granular kidney, or one form of Bright's disease. In both these cases, the parenchymal substance is diminished by the pressure consequent on the increase of this interstitial element.

2. This tissue is also, like all others, liable to atrophy, if its usual supply of blood be cut off; as by pressure upon the vessels by tumors, aneurisms, &c.

3. Pathological new formations of this tissue are very common, and constitute many of the pathological epigeneses. Fibroid tumors of the uterus are often formed of it without any admixture of the elastic element. Condylomata, warts, and vegetations on the skin and the mucous and serous membranes, are essentially new formations of collagenous tissue, usually covered by a distinct epithelium (p. 247). The walls of cysts are formed of white fibrous tissue, as well as most of the substance of nasal, laryngeal, and uterine polypi; though in all these cases, the loose arrangement of the fibres may rather entitle it to the name of areolar tissue. The same remark may also be extended to nævi materni.

Sarcomatous tumors are formed in great part of this tissue. The *keloides* is also a development of it in the corium of the skin, giving

rise to an appearance like a cicatrix. Even the *lupus exedens* is merely a development of white fibrous tissue in the corium of the skin; but in such a way as to cause atrophy and ulceration of its structure, and thus its progressive destruction.

The pathological development of white fibrous tissue alone, is not generally regarded as producing a malignant epigenesis. But this distinction of malignant and non-malignant is evidently of less importance, when we consider that the atrophy of the parenchyma of the liver from a hypertrophy of Glisson's capsule, is as sure to be fatal if it continues to progress, as is any form of cancerous development.

CHAPTER IV.

THE AREOLAR TISSUE.

Several different terms have been used by different histologists to designate this tissue. Long ago termed the *cellular tissue*, it has more recently been called the connective tissue; the reticulated connective tissue (*Kölliker*); the fibro-cellular tissue; the fibrous cellular (*Hassall*), and the *areolar* tissue (*Todd and Bowman*). Of all these, the last is the only appropriate name. The term "connective," as applied to any tissue has already been objected to (p. 275), though it is really more applicable to this than to any other, as expressing one of its functions. By a *cellular* tissue can, now-a-days, be meant only a tissue composed of an aggregation of cells, like the epithelium, &c.; and by a fibro-cellular, one composed of fibres and cells.

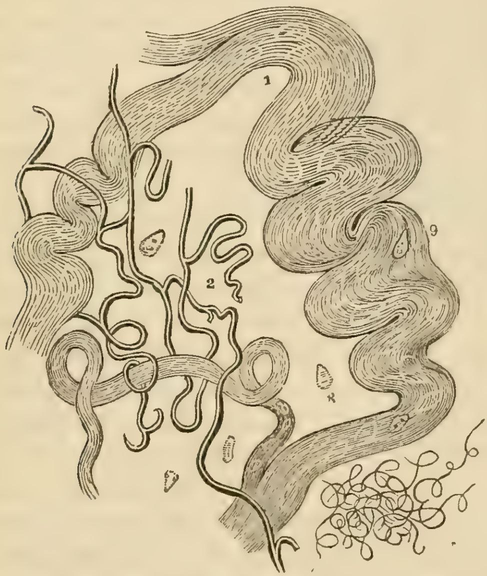
The tissue under consideration is composed of fibres so interwoven, either separately or in fasciculi, as to leave larger or smaller irregular spaces—*areolæ*—between them. And this arrangement constitutes the peculiarity of the tissue; for the fibres are those of the white-fibrous tissue and the yellow-fibrous tissue, just described. It has been seen that white-fibrous tissue is almost invariably accompanied by the yellow, as in the tendons, fibrous membranes, &c. (p. 278). But while in these the elastic element exists only in a very small amount, and both are so intimately blended as to form a very compact structure; in the areolar tissue the elastic element is more abundant, and the areolæ give rise to a loose and spongy tissue. A description is, therefore required:—

1. Of the solid fibrous tissues.

2. The areolæ and their contents.

1. The *collagenous element* (white-fibrous tissue) of the areolar tissue always greatly predominates over the elastic element, though varying in its precise proportional amount in different parts and organs. It occurs in fasciculi, as shown in Fig. 181, of a more or less wavy outline, and of various length and size; they frequently being about $\frac{1}{500}$ of an inch in diameter. Among these the *elastic fibres* are distributed, sometimes in bundles, but more frequently

Fig. 181.



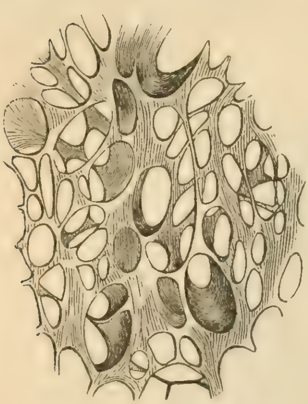
The two elements of the areolar tissue, in their natural relations. 1. The white fibrous element, with cell-nuclei (9) sparingly visible in it. 2. The yellow fibrous element, showing the branching or anastomosing character of its fibres. 3. Fibres of the elastic element, much finer than the rest. 8. Nucleolated cell-nuclei, often seen apparently loose. (Magnified 320 diameters.)

single, and being $\frac{1}{5000}$ to $\frac{1}{8000}$ of an inch in diameter. Frequently also they are coiled around the other fasciculi, as shown in the figure. Messrs. Todd and Bowman first called attention to the fact that this tissue is a compound of the two just mentioned. The elastic fibres are easily isolated from the white fibrous tissue under the microscope, by the action of acetic acid; which renders the latter indefinable, soft, and gelatinous (pp. 270 and 277).

2. The *areolæ* are merely irregular cavities between the solid

elements, just described. (Fig. 182.) They consequently have no distinct walls, and they freely communicate with each other. Their size varies extremely; sometimes occupying much more space in the aggregate than the solid portions, in which case the tissue is very loose; while in other cases they are very small, from a condensation of the fibres around them. It is this free communication which accounts for the ready diffusion of blood and other fluids in the areolar tissue under the influence of gravity. The smallest meshes, however, in some parts are so disposed as to constitute secondary cavities of a somewhat determinate shape and size, and which are visible to the naked eye. These generally contain fat-cells; and the much-branched, sometimes tubular, sometimes fissure-like spaces connecting them, are termed the *areolar passages.*

Fig. 182.



Portion of areolar tissue, inflated and dried, showing the general character of its larger meshes. Each lamina and filament here represented, contains numerous smaller ones, matted together by the mode of preparation. (Magnified 20 diameters.)

The *contents* of the areolæ are: (1), a fluid of an alkaline reaction, resembling a weak serum; or (2), fat-cells. This fluid is a mere transudation, and not a secretion, from the bloodvessels traversing the tissue, and its general composition has been specified on page 181. In some parts, however, the areolæ are partly or entirely filled by fat-cells; in which case the serous fluid is proportionately excluded. This is especially the case with the subcutaneous areolar tissue, or *superficial fascia.* But in certain parts, fat never accumulates; as underneath the skin of the eyelids, of the scrotum, &c.

The amount of fluid in the areolæ is liable to sudden increase or diminution, often from slight causes; the former producing œdema or swelling, and the latter a shrivelled appearance of the skin over the part in which it occurs.

Sometimes the areolæ become filled to a greater or less extent with air, to the exclusion of the fluid. Occurring as a pathological condition it constitutes *emphysema.* This may, indeed, be produced with the blowpipe experimentally; and Bichât tells of mendicants who excite the commiseration of passers-by, by the singular ap-

pearance produced by inserting a quill under the skin of the chest, and blowing forcibly through it—a general emphysema being thus promptly produced. The air is, however, removed by absorption within a few hours without any injurious results. This experiment also demonstrates the free communication of the areolæ with each other over the whole body even.

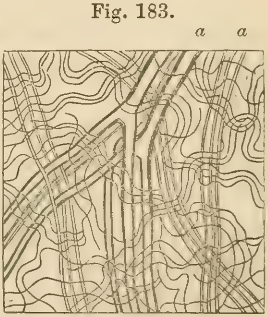
Chemical Composition of Areolar Tissue.

Areolar tissue abounds in water, since its serous fluid consists mostly of it. Besides, both the white and the yellow fibrous tissues contain a considerable percentage of it. Of course, glutin is obtained from areolar tissue by boiling; from the osteine contained in its white fibrous tissue. Elasticine exists in the elastic tissue. In addition to these, we have only to refer to the composition of the transudations for the amount of albumen and saline matters they contain (p. 182).

Properties of Areolar Tissue.

Areolar tissue has no characteristic vital properties, since this is the fact with regard to both of its two component elements. Like them it is distinguished by *physical* properties merely; the principal being extensibility and elasticity, with a good degree of strength. It owes the last property to the collagenous element, and the other two to the elastic tissue. If it be asked how a tissue formed in great part of an entirely inextensible element (the white fibrous tissue), becomes extensible, we have to remember that in extending the areolar tissue the individual fasciculi of white fibrous tissue are not stretched, but are merely displaced upon each other; while the elastic fibres restore them to their original relations after the tension is removed.

Fig. 183.



Vessels of areolar tissue from the neck of a young pig. *a*, *a*. Nerves. (*Queckett.*)

The only vital property manifested by this tissue is the one common to all the tissues mentioned thus far; viz., the power of maintaining its own nutrition. The nutritive changes are, however, probably but slowly brought about, after it is once fully developed, and the vessels in its substance are mostly on their way to other tissues.

Nor can the nerves detected in it be regarded as belonging to it, since they proceed beyond to terminate. Consequently, it manifests but a slight degree of sensibility when divided by the surgeon's knife. The *vessels* in areolar tissue are generally arranged so as to include hexagonal spaces, as seen in Fig. 183, from Queckett; and which also shows the appearance of the nerves.

Uses of Areolar Tissue.

The functions of areolar tissue depend on the physical properties just mentioned.

1. It isolates the various organs by constituting their external envelop.

2. It at the same time lies between and connects the various organs together in the body, and yet so as to allow of a certain amount of motion of one upon another. It is, therefore, the *true connective tissue* (p. 275).

3. It protects the proper substance or parenchyma of various organs.

4. It gives support to organs, and maintains them in their place. Thus, with few exceptions, it accompanies the bloodvessels and nerves to their minutest subdivisions.

It must, therefore, be regarded as a subordinate tissue, wherever found, though quite indispensable on account of the mechanical uses just described.

Distribution of the Areolar Tissue.

The areolar is more extensively diffused than any other tissue in the body. Indeed, it enters to such an extent into the structure of every part and organ, with very few exceptions, that if all the other tissues were entirely removed from the body, its conformation would still be preserved in every part by the areolar tissue; and, except from the removal of the osseous and the muscular tissues, its weight would be but slightly diminished, as the following particulars will show:—

1. It surrounds and supports the arteries and veins everywhere, and sometimes the capillaries also, and thus enters with the vessels into every organ.

2. It also forms sheaths (perineuria) around all the nerves; accompanying them, however, to their finest ramifications, in an undeveloped form (p. 276). The brain, however, does not contain

it, except as it surrounds the vessels, two or three removes from the capillaries.

3. Areolar tissue invests the *muscles* externally, forming their sheaths or *perimysia*, which give off prolongations (internal perimysia) investing the fasciculi of fibres. The heart, however, contains this element in very small proportion, its fibres intertwining in such a manner as to render an extraneous bond of connection unnecessary. It also lies between and underneath the muscles, and in greater quantity in proportion to the required mobility.

4. This tissue is abundant around internal organs which undergo changes of form, size, or position in the performance of their functions, and which are partially or wholly without a free surface, as the pharynx, œsophagus, bladder, lumbar colon, &c.; and its filaments are long, tortuous, and largely intertwined. It also envelops all the glands, and sends prolongations into their interior among their lobules; it being more abundant in proportion as the gland is less compact, and allowing motion of one part upon another. *E. g.* it is far more abundant in the mammary gland than in the liver.

5. Under the skin and the mucous and serous membranes, it forms a distinct layer, though presenting great varieties in respect to quantity and denseness.

6. Finally, the corium of the skin and of mucous and serous membranes is merely condensed areolar tissue, as will be seen.

Peculiarities of Areolar Tissue.

A peculiar form of areolar tissue is said by Henle to exist in company with the arteries at the base of the brain; the elastic fibres forming rings and spirals around the fasciculi of the white fibrous tissue.

The subcutaneous areolar tissue is also of peculiar practical importance, and will therefore receive some additional notice here.

The Subcutaneous Areolar Tissue.

The layer of areolar tissue under the skin was formerly called the *cellular membrane.* It is properly termed the *superficial fascia,* or the subcutaneous areolar tissue. It, singularly enough, is described by Kölliker as one of the layers of the skin itself; and whenever it contains fat-cells in its areolæ, it is by him called the *panniculus adiposus.* He also restricts the term *superficial fascia* to

its innermost layer, where, as upon the trunk, thighs, &c., it forms a tolerably firm texture without fat-cells.

The *inner surface* of the subcutaneous areolar tissue is most loosely adherent to the subjacent parts upon the trunk, the forearms, legs, the back of the hands and feet, the eyelids, penis, and scrotum, and on the extensor side of the articulations. A closer connection exists where tendinous fibres or processes are inserted into the skin (levator labii superioris, palmaris brevis, &c.); and where this tissue is connected with subjacent muscles by short, strong filaments of white fibrous tissue, as on the head, alæ nasi, and lips, the forehead and temples, the ear, mouth, and occiput; also on the glans penis, beneath the nails, &c. Generally the skin is less movable where the fat forms a thick layer, than where, from any reason, it is less abundant, or entirely absent.

The *external* surface of the subcutaneous areolar tissue is connected by numerous filamentous processes of white fibrous tissue with the *corium* of the skin, and is not everywhere distinct from the latter, as under the skin of the penis and scrotum (dartos). Generally, however, the areolar tissue is pretty easily separable from the skin, especially where the former contains an abundance of fat; except where the follicles of the larger and more closely-set hairs penetrate deeply into the fat, as on the head, cheeks, chin, &c.

The *thickness* of the subcutaneous areolar tissue varies much in various situations. That of the eyelids and the upper and outer part of the ear is $\frac{1}{48}$ of an inch thick; of the penis, $\frac{1}{36}$; and of the scrotum, $\frac{1}{18}$ of an inch. (*Krause.*) In these situations there is no fat; in those next mentioned there is. On the cranium, brow, nose, lobe of the ear, back of the hand and foot, the knee and elbow, the thickness is 1 line, while in most other situations it is $\frac{1}{6}$ to $\frac{1}{2}$ of an inch thick. The thickness, however, in the same part, varies with the age, sex, and the individual. Women have more fat in its areolæ, generally, than men; and hence a greater thickness of this layer, as well as a greater plumpness of form. It is thicker, proportionally, in healthy infants and children than during adolescence. In corpulent persons the subcutaneous areolar tissue may become so laden with fat as to be 4 inches thick even; while in lean persons, in the same situation, it may not exceed 1 line.

Similar extremes in thickness may also present themselves in the same person on passing from a state of emaciation to one of corpulence, or the reverse. And this is a fact of great practical import-

ance to the surgeon, especially in regard to the making of incisions preliminary to the ligation of arteries. It is, of course, only in situations where the areolæ are large, and filled with fat-cells, that these changes occur; as on the abdomen, the neck, and the limbs especially. It less affects the back of the trunk, since there the tissue is much more condensed, and the areolæ are therefore very small.

Development of Areolar Tissue.

In the earliest period at which the areolar tissue can be examined, Schwann has described it as consisting of nucleated particles, sending offsets on the opposite sides, and uniting themselves with others in the vicinity. The threads thus formed are at first homogeneous; the longitudinal streaks and the wavy character appear subsequently. Normally and originally, however, we believe that the yellow fibrous element alone is developed from cells (p. 283).

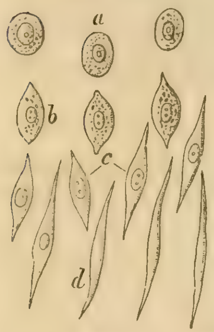
The development of areolar tissue consists, in fact, merely of the simultaneous development of the white and the yellow fibrous tissues in the same blastema. These elements subsequently become blended, as found in the different situations already described.

When new formations of areolar tissue occur, however, as in inflammatory exudations, subcutaneous wounds, &c., the white fibrous element may be developed either from cells or directly from the plasma, as has been shown by Mr. Paget.

1. In case of repair by granulation, and of inflammatory adhesions and indurations, the white fibrous element of the areolar tissue is developed from *cells*. "The cells first formed in the plastic exudation are round, very slightly granular, and from $\frac{1}{1500}$ to $\frac{1}{2000}$ of an inch in diameter; they have a distinct cell-wall, which is readily brought into view by the action of water, if not apparent at first: and they present a round, dark-edged nucleus, whose sharp definition distinguishes it from that of the colorless corpuscles of the blood, to which these cells otherwise bear a close resemblance. It is in this nucleus that the first developmental change shows itself, for it assumes an oval form, and its substance becomes clearer and brighter. Very soon, however, the cell itself elongates at one or both ends, so as to assume the caudate, fusiform, or lanceolate shape (Fig. 184); and its contents become more minutely and distinctly granular, whilst the cell-wall thins away, or becomes blended with its inclosure. As the cells elongate more and more, so as to assume the filamentous form, they also arrange themselves in such a manner

that the thickest portion of one is engaged between the thinner ends of the two or more adjacent to it; and thus fasciculi are gradually formed, of which every fibre is developed from one elongated cell, except where two or more cells have united end to end, so as to form one long, continuous filament. In the production of areolar tissue in inflammatory exudations, or in granulating wounds, the nuclei of these fibre-cells appear to waste and be absorbed: but in the normal course of development, which may be seen to take place on this plan in the subcutaneous areolar tissue of the fœtus, as well as in many other situations, it is probable that they develop themselves into the 'nuclear fibres' of Henle, which constitute, in fact, the yellow or elastic filaments that are intermingled with the white in this tissue"[1] (p. 273).

Fig. 184.



Development of fibres from cells. *a* Circular or oval nucleated cells. *b.* The same, becoming pointed. *c.* The same, become fusiform, the nuclei being still apparent. *d.* The same, elongated into fibres, the nuclei having disappeared.

2. In case of the filling up of subcutaneous wounds, as of tendons especially, the white fibrous element is formed directly by the *fibrillation* of a nucleated blastema. This, when first effused, "seems like a mere fibrinous exudation, usually containing a quantity of finely-molecular or dimly-shaded substance, but having no appearance of distinct nuclei; these, however, gradually present themselves in it, as oval bodies, with dark, hard outlines, which soon become elongated, and are so firmly imbedded in the surrounding substance that they can scarcely be dislodged. The blastema gradually acquires a more and more distinct fibrous appearance, and at last exhibits a regular filamentous structure; the nuclei themselves undergoing little change during this time, but appearing to govern the direction of the fibrillation. As the texture goes on to completion, the nuclei are either absorbed—which seems to be the case in the connecting tissue formed for the reparation of injuries, as well as in the normal development of tendons—or they undergo a further development into 'nuclear fibres.' This is effected by their extension at both ends, so that the nuclei thus prolonged meet and unite; their particles taking on that very uniform linear arrangement by which the

[1] Paget's "Lectures on the Processes of Repair and Reproduction after Injuries," in Medical Gazette, 1849, vol. xliii. p. 1069.

fibres of this tissue (*i. e.* the yellow fibrous) seem to be characterized, and sometimes perhaps undergoing a partial or complete development into cells. The rate at which the production of fibrous tissue takes place in the manner now described is at first very rapid, well-marked filaments being detectable in the blastema within seven or eight days; and the tenacity of the bond thus formed between the two ends of a divided tendon is such that in one of Mr. Paget's experiments, within ten days after the operation, the reunited tendo-Achillis of a rabbit (the new tissue being a cord of not more than two lines in its chief diameter), supported a weight of above fifty pounds. The subsequent changes take place more slowly; but the reparation of divided tendons has been found to be so complete within five months after the operation, that no trace of the sections could be discovered even by microscopic examination."[1] It is, however, to be remembered that *non-inflammatory* exudations alone can become organized in this way; they passing at once into tissues, while the inflammatory require an intermediate process of cell-life to accomplish the same result (p. 186).

Regeneration of Areolar Tissue.

Areolar tissue is very perfectly regenerated if removed; but the most completely so in situations where it is most condensed, or approaches more nearly to mere white fibrous tissue.

Indeed, it is an imperfectly-developed areolar tissue, rather than the original one, which repairs losses of substance in most parts and organs, as the skin, tendons, and even the parenchyma of organs—as when parts of the liver or brain, &c., are removed by suppuration or by injury.

Pathological States and New Formations of Areolar Tissue.

Here we have to distinguish the pathological conditions—

I. Of the fibrous framework of this tissue.
II. Of the areolæ and their contents.

I. The fibrous framework is liable to atrophy, in which the blood-vessels collapse, together with the framework in which they are distributed. It is quite probable that the *hypertrophy*, so called, of the areolar tissue is a new formation of the same.

II. But the most important changes occur in the contents of the areolæ.

[1] Paget, "Lectures," &c., *ut supra*, p. 1070–71.

1. An increase of the natural serous fluid of the areolæ constitutes *œdema* or swelling; and if of considerable extent, and occurring in the subcutaneous areolar tissue, it constitutes *anasarca* or dropsy, and which usually occurs in the lower limbs first, for the reason specified at the end of the next sentence. In dropsy, moreover, the tissue yields to pressure, or "pits," since the fluid is forced from one areola to another; and it also passes from one part to another under the influence of gravity.

2. In case of *inflammation* in the areolar tissue (areolitis), the areolæ become filled with an exudation instead of the natural transudation, and which may become subsequently organized (p. 187). If so, the areolar tissue presents an indurated feeling, since the areolæ are filled by a solid substance; and the skin becomes quite immovable over the indurated portion.[1]

3. If the exudation filling the areolar tissue degenerates into pus, it will be evacuated by ulceration, if it is not so artificially.

4. A sudden *diminution* of the fluid in the areolæ sometimes occurs, as in Asiatic cholera and other diseases attended by profuse liquid alvine discharges. Here the fluid is absorbed into the blood directly, to compensate the loss from this fluid by the transudation into the alimentary canal from its vessels. The immediate effect is a rapidly-induced shrivelled appearance of the skin; and which is more apparent in infants, while it is also soonest removed in them after the discharges cease.

5. *Extravasated blood* may accumulate in the areolæ, and gravitate from one to another, as is seen in case of *ecchymosis* under the skin. The blood is removed by absorption, or, undergoing a change, is discharged by the ulcerative process.

6. The normal fluid in the areolæ may be replaced by air, constituting a *pneumatosis* or *emphysema*. This may result from decomposition in the tissue, but more frequently from the air being forced into the areolæ from without. In the latter case it may be soon reabsorbed without producing injurious consequences (p. 286).

7. Fat-cells may fill the areolæ where they do not usually exist, or may greatly increase where ordinarily found. This state is, however, rather a hypertrophy of the adipose tissue, as will be seen. It, however, interferes with the elasticity of the areolar tissue, and thus with the mobility of parts and organs; and so far produces a pathological condition of the tissue under consideration.

8. In case of atrophy of this tissue, the areolæ are filled with plates of cholesterine, pigment-cells, and often also the carbonate and phosphate of lime.

9. The subcutaneous areolar tissue is the seat of numerous pathological changes, especially sarcomatous and lipomatous tumors. The surgeon must also bear in mind the changes in thickness it under-

[1] An areolitis sometimes occurs in the superficial fascia of new-born children, and is sometimes termed the "skin-bound" condition.

goes—as has been stated (p. 291)—in case of ligation of the large arteries, since they lie under the deep fascia, which does not vary in thickness, and require a division of the superficial fascia to arrive at the latter.

10. Reparative *new formations* of areolar tissue have already been described (p. 292). Pathological new formations are not infrequent; often constituting, as they do, the stroma of cancerous growths, in the areolæ of which the cancer-cells are deposited. It is, however, often very difficult to decide, in particular instances, whether a pathological new formation consists mainly of the white fibrous or of the areolar tissue, on account of its imperfectly-developed state; and some of the formations mentioned on page 283 would by some observers be regarded as of the areolar, rather than of mere collagenous tissue.

CHAPTER V.

ADIPOSE TISSUE.

ADIPOSE tissue and fat, are terms often used to denote the same thing. But we have seen that human fat is a fluid—a compound of oleine, margarine and stearine; the first holding the other two in solution (p. 76, 1). It is also found constituting in part the granules in almost all kinds of cells (epithelial, &c.), and in the form of minute drops (fat globules), in the interstices of many tissues (p. 73).

But in adipose tissue, the fat is contained in, and completely fills the adipose *cells;* and the tissue consists of the two following elements:—

I. The adipose, or fat-cells.

II. A matrix of areolar tissue diffused among the cells, and holding them together—the intercellular areolar tissue.

I. The *adipose cells* (Fig. 185), are peculiar in several respects. 1st. They contain no granules; but only the clear fluid before mentioned. 2d. When fully developed, they have no apparent nucleus or nucleolus; though Kölliker always finds a nucleus when they are but partially filled. 3d. The cell-wall is apparently of simple

membrane, but very thick comparatively—even $\frac{1}{1000}$ of an inch.[1] 4th. The fat-cell is also larger than other cells, being from $\frac{1}{1125}$ to $\frac{1}{187}$ of an inch (*Kölliker*), and averaging $\frac{1}{600}$ of an inch in diameter. They are smallest in young animals. Those, however, of the same mass differ in size. They present no peculiarity in respect to form;

Fig. 185.

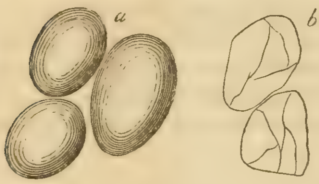


Fig. 186.

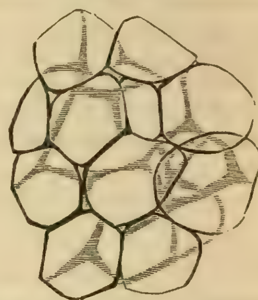


Fig. 185. Normal fat-cells from the breast. *a*. Without reagents. *b*. After being treated with ether, whereby the fat is exhausted and the folded delicate membrane remains.—Magnified 350 diameters. (*Kölliker*.)

Fig. 186. Fat-cells assuming the polyhedral form from pressure against one another; from the omentum. (Magnified about 300 diameters.)

being globular originally and in young animals, and polygonal when pressed together in a mass in the adult. (Fig. 186.)

In color, adipose cells are usually of a yellowish shade; but lighter in young than adult animals. Hence adipose tissue is usually of this color.

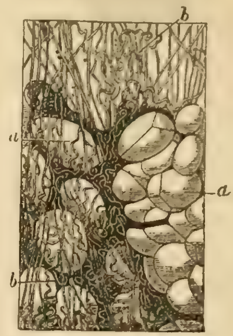
The *contents* of the fat-cells become solid at the temperature of 63° (Fahr.) and lower, since the oleine congeals at this temperature. After death, therefore, human fat is solid.

II. The connective tissue between the fat-cells usually presents nothing peculiar, it being mere areolar tissue. It is, however, sometimes merely a connective substance or plasma. (*Kölliker*.) It has already been shown that fat-cells often fill, partially or entirely, the areolæ of areolar tissue, as of the superficial fascia; though a small amount of areolar fluid still exists between the cells, except where they are in perfect contact. But in case of adipose tissue, the cells are aggregated in larger masses, and the connective areolar tissue is comparatively slight in amount. These masses take the

[1] Todd and Bowman think each fat-cell has its own envelop of areolar tissue, and its distinct vessels. This is, however, certainly not the case with all of them, though it is with some.

form of lobes or lobules, which are also bound together by still larger fasciculi of areolar tissue. The relations of the fat-cells and the intercellular connective tissue are shown by Fig. 187.

Fig. 187.

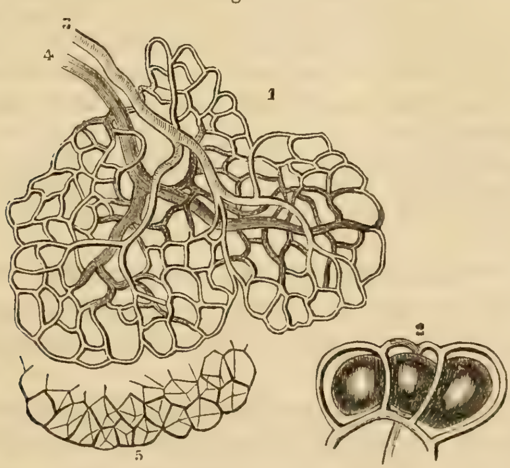


Adipose tissue. *a, a.* Fat-cells. *b, b.* Fibres of intercellular areolar tissue.

Vessels of Adipose Tissue.—Each fat-cell is surrounded by a loop or loops of capillary bloodvessels; all the capillaries of a single terminal artery looping around the cells of a single lobule. (Fig. 188.) Hassall compares such a lobule of cells to a bunch of grapes. The vessels of the lobule do not, however, apparently grow from the cells like the stems of grapes, though there is a general analogy. No nerves or lymphatics belong to the adipose tissue, though both may be found traversing it on their way to other tissues.

Peculiarities.—Sometimes a minute star-shaped body may be seen in a fat-cell in the human subject. (Fig. 189.) This is generally

Fig. 188.



Bloodvessels of fat. 1. Minute flattened fat-lobule in which the vessels only are represented. 3. The terminal artery. 4. The primitive vein. 5. The fat-cells of one border of the globule separately represented. (Magnified 100 diameters.) 2. Plan of the arrangement of the capillaries on the exterior of the cells, more highly magnified.

said to consist of the margarin in a crystalline form. Kölliker, however, regards it as margaric acid. This appearance is more common in the aged.

Fig. 189.

Fat-cells with crystals of margaric acid. *a.* Cell with a star of crystalline needles, as they may be found not uncommonly in normal fat. *b.* Cell quite filled with crystals, from the white fat-lobules of an emaciated subject.—Magnified 350 diameters. (*Kölliker.*)

In the emaciated subject scarcely any normal fat-cells are met with; but this topic will be resumed in the last subdivision of this chapter.

Peculiarities in the Lower Animals.

Fat-cells do not exist in the invertebrata, though fat-globules do (p. 73), and often in great abundance. There is, therefore, in them no true adipose tissue. The larvæ of insects contain a large amount of fat-globules.

The fat-cells of the pig are generally somewhat kidney-shaped. In birds, they are smaller than in man, and often contain a bright colored fluid; *e.g.* the bright colors about the beak, and of the legs in some species, are said to depend on layers of cells beneath the skin containing colored fat. The bright colors of certain crustaceans and reptiles, are also due to a similar cause, when not dependent upon pigment-cells. Wagner believes that the color of the iris in birds is also due to a deposit of fat.

The fat of different animals presents four varieties, so far as its density after death is concerned; viz., oil, lard, tallow, and spermaceti—the first containing the most oleine, and the last the most stearine. The fat of the bear does not congeal at ordinary temperatures, *i.e.* it remains an *oil;* and hence its value to perfumers. Lard is obtained from the hog; tallow from the ox, sheep, &c., and spermaceti from cavities in the cranium of the whale. Human fat is intermediate in density between lard and tallow. The fat upon the omentum of the sheep is called suet.

Chemical Composition of Adipose Tissue.

This includes, (1) the composition of the fluid fat itself; (2) that of the walls of the fat-cells; and (3) of the intercellular areolar tissue.

1. If adipose tissue be exposed to a high temperature the fat-cells burst, and the fat escapes; the cell-walls and the areolar tissue forming a solid residue. It has already been shown that the fat consists of oleine, stearine, and margarine; and their composition has been specified on page 76.

2. The composition of the cell-wall is not precisely known; but there is no room to doubt that it is an albuminous compound.

3. The intercellular areolar tissue has the same composition as areolar tissue in other situations (p. 287).

It should be added that a small amount of serous fluid bathes the fat-cells—the *intercellular fluid;* and which does not differ in composition from that in the areolæ of the areolar tissue.

Distribution of Adipose Tissue in Man.

This tissue is very generally diffused throughout the human organism, and in the adult usually constitutes about $\frac{1}{20}$ part of the weight of the body. In women and children, however, it averages somewhat more than this proportion.

It has been seen (p. 290), that fat-cells exist in the areolæ of the superficial fascia, in most situations. This is, however, not much developed in the fœtus till the sixth month, and hence a fœtus born at or before this period, has a peculiar shrivelled look; while at the full term it is plump and well-rounded. Some of the areolar fluid also remains between the fat-cells in the superficial fascia.

In the following parts, fat is most abundant in the adult; upon the soles of the feet and the palms of the hands; upon the pubes and the nates; around the mammary gland of the female; upon the great omentum, and beneath the skin of the abdomen.[1] It is also accumulated between the inner layer of the pericardium and the substance of the heart; around the origin of the large vessels; in the orbital cavity; in the spinal canal, outside of the theca vertebralis, and in the medullary cavities of the bones. In cases of the extremest emaciation, the fat does not entirely disappear in the parts mentioned in the preceding sentence. Fat is also deposited around joints, and in many fossæ. The fat in bones is called marrow, and differs from ordinary adipose tissue only inasmuch as its cells contain somewhat more oleine (*Lehmann*); are more globular, from not being exposed to pressure; and in containing but a slight admixture of areolar tissue.

On the other hand, since the contents of the fat-cells are liable to undergo sudden variations in quantity, there are certain parts in which no adipose tissue is ever found. These are the eyelids, the ears (except the lobule), the lungs, the penis and scrotum, the clitoris, the nymphæ, between the rectum and bladder in the male, and between the rectum and vagina in the female; on the brain and

[1] In those situations where the areolæ of the subcutaneous areolar tissue inclose fat-cells, Kölliker terms it the *panniculus adiposus.*

in the axilla; and hence these parts (except the brain) become highly œdematous (p. 294, 1) from inflammation, contusions, &c.; as the parts whose areolæ are filled with fat-cells cannot. Besides, it does not exist under the epicranial aponeurosis, under the mucous membranes,[1] in the corium of the skin, nor between overlapping muscles.

The fat in the brain and nerves, is not in the form of adipose tissue—not in fat-cells; but enters into the chemical composition of the tissues themselves.

Fat-cells are never entirely absent in the heart, in the orbit, and between the muscles of the face.

Peculiarities of Distribution of Fat.

The adipose tissue under the skin of the abdomen sometimes accumulates to a great amount, in one instance forming a layer 14 inches thick! This increase is most likely to occur in men at the age of about forty years. Occurring also in women at this period, or somewhat earlier, and most frequently in those who have never had children, the consequent enlargement has sometimes been mistaken for a time for pregnancy.

It has been observed that Hottentot women manifest a peculiar tendency to the accumulation of fat upon the nates; which does not, however, appear till after the birth of a child. This is by them considered an important element of female beauty. In all male animals, on the other hand, a tendency to accumulate fat is produced by castration. It often also accumulates in women when they cease to conceive, and in those who are barren.

Certain individuals are remarkable for the accumulation of fat upon the body generally, while others are as remarkable for a destitution of it. A Greek writer tells of a person who was obliged to attach iron to his sandals, lest he be blown away when he went abroad. On the other hand, Daniel Lambert, the Lancastershire giant, weighed 739 pounds; the circumference of his body being 9 feet 4 inches, and of his leg, 3 feet 1 inch. His coffin was 6 feet 4 inches long, 4 feet 4 inches wide, and 2 feet 4 inches deep. The author saw a young woman in Paris, 18 years of age, who weighed over 500 pounds. Paolo Moccia was so fat as to weigh 30 pounds less than his bulk of water, and consequently he could not

[1] An exception is found in the soft palate, where there is an abundance of yellow fat, often seen through the membrane in the case of anemic subjects.

sink in water. And a Spanish general, who was enormously corpulent, is said to have removed the fat so rapidly by drinking large quantities of vinegar, that he could wrap the loose skin around him like a cloak.

Such extreme degrees of obesity must, however, be regarded rather as a pathological condition, and which is incompatible with a long life. So great a weight of fat encumbers the heart especially, and hence the pulse becomes feeble, and loss of blood is not well tolerated. In view of the ultimate consequences, therefore, this condition (called polysarcia) often requires the adoption of means to diminish the amount of fat. The author is cognizant of an instance in which this object was very promptly secured by the use of nitric acid. But it has been shown by Dr. T. K. Chambers, in his "Lectures on Obesity,"[1] that the most reliable remedy in such cases is the liquor potassæ. It is possible that the fat is reabsorbed into the blood from the fat cells, to combine with the potassa and form a soap or emulsion; after which it is burned up by combination with oxygen, as a calorific element. For such an absorption into the blood, doubtless occurs from the fat-cells in cases of emaciation; and Henle has seen the blood so laden with fat after a profuse hemorrhage, that it formed a distinct pellicle on its surface.

A superabundance of adipose tissue, or a privation of it, has alike, in all ages, been regarded as a legitimate subject of derision. Sir John Falstaff is the impersonation of the class included in the first category, except perhaps in respect to his activity; who represents himself as being "a man of continual dissolution and thaw," and who had "a kind of alacrity in sinking."[2] The dramatist has, however, committed a physiological mistake in the last expression, as has already been shown. He has, however, in another passage, recognized the effect, in diminishing the deposit of fat, of intense and continued intellectual effort and anxiety, and consequent loss of sleep:—

> "Let me have men about me that are fat;
> Sleek-headed men, and such as sleep o' nights.
> Yond' Cassius has a lean and hungry look:
> He thinks too much: such men are dangerous."
>
> *Julius Cæsar*, act i. sc. 2.

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[1] London Lancet, for 1850, vol. ii. p. 443.

[2] "You may know by my size that I have a kind of alacrity in sinking."

"Think of that; a man of my kidney—think of that; that am as subject to heat as butter; a man of continual dissolution and thaw. It was a miracle to escape suffocation."—*Merry Wives of Windsor*, act iii. sc. 5.

It has been sometimes remarked that fat men can endure loss of sleep better than the lean. So far as this is the fact—and it is believed to be generally true—the author is inclined to associate it with more active powers of nutrition, which secure the deposit of fat in spite of the privation of sleep. The dyspeptic, on the other hand, requires more sleep; though with it, even, he remains lean. There is, however, in some, a constitutional tendency to deposit fat; and who, though they become confirmed dyspeptics, still continue in good condition in this respect. Indeed, there are also national differences in this respect. Englishmen are more prone to corpulence than Americans; a result, probably, of the combined influence of a freer use of fermented liquors, and of a damper climate in England; for the former contain elements favorable to the deposition of fat, and the latter induces a less active condition of the skin. The Bedouin Arabs are, on the other hand, remarkable for their leanness; for which their simple and spare diet and the dry atmosphere in which they live, together with their active habits, must mainly account.[1]

Circumstances modifying the Deposit of Fat.

A constitutional tendency to deposit fat has been alluded to; but several circumstances also exert a powerful influence in this respect. The most important are:—

1. The kind of diet.
2. The amount of exercise.
3. The state of the function of respiration.

1. The non-nitrogenized elements of our food—starch, sugar, gum, dextrine, and fat—tend specially to the development of fat. So also do distilled and fermented liquors.

[1] Not a few *epitaphs* have been suggested by the present subject, and two may be forgiven here. The first commemorates the burial-place of a remarkably corpulent deacon:—

"Take heed, gentle traveller, and do not tread hard,
For here lies Deacon Stafford *in all this churchyard.*"

The other epitomizes the life and the death of an honest tallow-chandler, who, becoming very wealthy from success in business, retired to the country, and there became so obese from inaction, that he died in consequence:—

"Here lies in earth an honest fellow,
Who *died* by *fat*, but *lived* by *tallow.*"

2. A sedentary or a sluggish life also favors the deposit of fat. Even carnivorous animals, though always lean in their natural state, become fat when closely caged, and fed on a mixed diet.

3. Breathing an atmosphere imperfectly supplied with oxygen, is a third cause of fatty deposit. To this we may also, doubtless, add privation of solar light, and a damp atmosphere.

4. On the contrary, a diet more exclusively nitrogenized (albumen, musculine, &c., as in eggs and lean meat), abstinence from distilled and fermented liquors, and habitual active exercise in the open air, tend to prevent an accumulation of fat, or to remove it if already existing.

Moreover, emaciation may be induced by a prolonged discharge of any fluid containing a considerable proportion of fat. Hence profuse suppuration or hemorrhage, or excessive sexual indulgence, produces leanness, since pus, blood, and semen are rich in fat (p. 74).

While the fat in the fat-cells is the most rapidly formed, it is also the most rapidly resorbed, of all the immediate principles of the human body. It is its sudden diminution around the eyeball which gives the sunken appearance to the eye, even a few hours after the invasion of certain acute diseases. This change is most rapid in children; and they also most rapidly refill the fat-cells when convalescence is established.

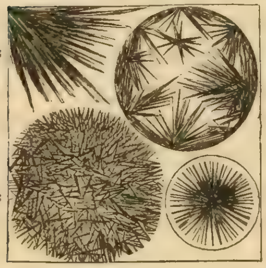
Distribution of Adipose Tissue in the Lower Animals.

Carnivorous animals are naturally lean, since they are necessarily active, and live principally on the nitrogenized immediate principles contained in the flesh of other animals.

Herbivorous animals, on the other hand, manifest a tendency to accumulate fat. They are less active, and consume large proportions of starch and gum. By way of exception, however, the rabbit is said to be almost entirely destitute of fat, and in some instances none at all can be discovered. There is a species of sheep in Asia which accumulates a mass of fat which is situated in the place of a tail; which swings to and fro as the animal walks, and sometimes weighs even 40 pounds. Fat is, however, usually most abundant, in ruminating animals, about the kidneys. In others it abounds in the mesentery and the omentum; and in others still, in the areolar tissue under the skin. The latter, in the seal and the whale, is called "blubber;" and from a single whale 120 tons are sometimes obtained—the deposit being from 4 to 20 inches thick. *Spermaceti* is, however, found in the sperm-whale, in two cavities of the cranium; while the cells of the adipose tissue also contain crystals of it. (Fig. 190.) The

cranial cavities sometimes yield 20 tons. Hibernating animals lay up a large store of fat as the winter season approaches, and which is consumed to maintain the animal heat during their dormant winter state. Hence they are found to be again comparatively emaciated on emerging in the spring from their winter quarters. In the camel, the "humps" are masses of adipose tissue, and are absorbed to sustain the animal, if suffering from privation of food.

Fig. 190.



Adipose tissue of sperm-whale. A, A. Cells containing crystals of spermaceti. B, B. Crystals of spermaceti on the outside of cells. (*Queckett.*)

In *birds*, fat is found deposited principally between the abdominal muscles and the peritoneum. In aquatic birds it is deposited in the bones of the legs, and the last bone of the wings and of the tail.

In *reptiles*, fat is found chiefly in the abdomen.

In fishes, fat-cells are distributed throughout the body generally, except in the cod, the haddock, and the whiting. In all these, fat is found only in the liver. (See p. 79.)

It has been seen that fat-cells do not exist in the invertebrate animals. Fat, however, abounds, in the form of globules, in the mollusca (oyster, &c.); and in the insect, both in the pupa and in the perfect (or imago) state.

The *trying out* the fat of the lower animals consists in heating the adipose tissue till the fat-cells burst and set free their contents. The *scraps* are the remaining areolar tissue and vessels.

Uses of Fat as a Tissue.

Adipose tissue fulfils merely chemico-physical offices in the organism.

1. It renders the skin soft and flexible. Reference is here made to the fat in the superficial fascia, or subcutaneous areolar tissue.

2. It gives roundness and symmetry, and hence grace and beauty, to the body. Hence it is more abundant in the female.

3. It is a protection against pressure; as on the nates, mons veneris, lacteal glands, &c.

4. It facilitates motion; as package between muscles, as deposited under the skin, around the eyeballs and the heart, and in the omentum.

5. It is a protection against cold, being a bad conductor of heat. Thus it is found under the skin, around the heart and large vessels, the lacteal glands, in the great omentum, &c.

6. Fat, by its low specific gravity, renders the human body lighter than its bulk of water in proportion to its amount. Hence it is an aid in swimming.

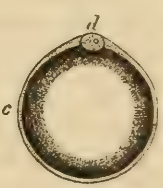
7. Lastly, the fat in the adipose tissue may become useful as nutritive material in cases of emergency; the fat being reabsorbed into the blood, and then becoming "fuel for respiration" (p. 77, 2).

Fluid fat alone is, however, merely calorific, and will not long sustain an animal (p. 76, 3). But adipose tissue, taken as food into the stomach, will nourish for a long period, as demonstrated by Magendie; since it also contains albuminous elements in its cell-walls, and osteine in its areolar tissue. The fact that all cells need fat for their development, since all nucleoli consist of fat (*Hunefeld*), has already been specified (p. 78, 5). Hence its necessity in the blood; whence it is also derived for the formation of bile and other secretions (p. 77, 2). The use of fat in the food, as an aid to digestion, has also been specified (p. 78, 5); and Lehmann suggests that the pancreatic fluid owes its power in this respect to the fat it contains. But in all these fluids we find mere fat-globules, and not fat-cells.

Development of Adipose Tissue.

The adipose or fat-cell manifests no peculiarity in its development. At first small and nucleated, it subsequently increases in size, and its nucleus disappears. Kölliker never fails to find the nuclei, however, when the cells are only partially filled with fat; and it must therefore be persistent. (Fig. 191.)

Fig. 191.



A fat-cell to show the nucleus; from Schwann. *c.* Cell-wall. *d.* Nucleus.

The first lobules of fat appear in the fourth month of intra-uterine life, in the palms of the hands and the soles of the feet. The subcutaneous adipose tissue is rapidly developed from the seventh month to birth. Hence the fœtus at five or six months has a wrinkled condition of the skin generally.

Is the fat in the organism formed from fat alone in the food? There is reason to believe not only that starch, sugar, &c., may be converted into fat in the organism, to a very slight extent, but that even from albumen also fat may be formed in small quantity in the alimentary canal (p. 74). Still, neither of these two points can be regarded as established. (*Lehmann.*[1])

[1] Physiological Chemistry, vol. i. pp. 230–32.

Growth of Adipose Tissue.

Hassall maintains that the fat-cells of each individual persist through life; they being merely larger or smaller, or more or less full, in the varying states of the adipose tissue. In cases of extreme corpulence, however, there can be no reasonable doubt of their increase in number. Hassall finds the fat-cells several times smaller in infants than in adults; and they doubtless increase after birth, as do the cartilage-cells (though probably more slowly), in size rather than in number.

The growth, however, appears to proceed at different rates in different parts of the body after birth, and also in the same part in different persons of the same age. Harting states that in the adult the fat-cells in the orbit are twice as large, and in the palm three times as large, as at birth.

Regeneration.—It is doubtful if fat-cells are reproduced after a mass of the adipose tissue is removed; the loss being repaired by a more condensed areolar tissue, such as usually constitutes the substance of cicatrices.

Pathological States and New Formations of the Adipose Tissue.

I. *Atrophy* of the adipose tissue is one of its most common pathological conditions, occurring in all cases of emaciation, and in anasarca. Here either the cells are partially collapsed, or their contents become changed. Kölliker specifies the following conditions of the contents of atrophied fat-cells:—

1. The cells are granular, containing numerous small fat-drops, forming whitish-yellow clustered lobules.

2. Cells containing a dark globule only of fat, the rest of their contents being removed.

3. Cells containing serum alone, the fat having been entirely removed.

The last two varieties occur in anasarca. Kölliker states that in this disease the cells also assume a stellate form (with from three to five processes), and become diminished in size. Wedl, however, suggests that these are young cells of white fibrous tissue.

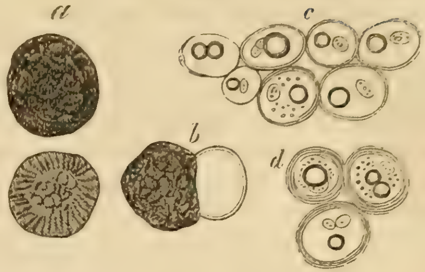
When the fat leaves the cells, it must first be mixed with the intercellular fluid, and then reabsorbed by the lymphatics. It is the accumulation of the serous fluid in the areolæ of the areolar tissue in dropsy, which causes the fat in the cells to disappear, partly perhaps by exosmosis; when the fat-cells become entirely filled, in turn, with the serous fluid.

4. Fat-cells containing crystals of margaric acid, with a drop of fat; or which are entirely filled with the former.

The varieties just mentioned are represented by Fig. 192; and in all of them the nucleus and nucleolus become very distinct.

5. Wedl adds another variety, in which the fat is subdivided into a multitude of globules, often grouped around a lighter-colored space (serum).—In many of these cases the cell-membranes are no longer visible, they having doubtless been dissolved; and no vestige of the nucleus can be perceived. He also finds that the cell-membrane is thickened in some cases of atrophy of the cell-contents, several concentric layers being visible on its inner aspect. These two conditions are shown by Fig. 193, where three normal fat-cells are also added, for the sake of comparison.

Fig. 192.



Atrophied fat-cells from the subcutaneous areolar tissue of an aged and much-emaciated person. *a.* Fat-cell shrunken, with crumbling, dark brownish-yellow contents; beneath it one of lighter color, with crystals radiating towards the border. *b.* An atrophied pigmented fat-cell in apposition with one in the normal condition. *c.* Cells filled with a serous fluid, and presenting in their contents well-marked circles (fat-globules in suspension), and delicate, oval, simple or double granules (nuclei). *d.* Cells containing serum, and whose walls are laminated.—Magnified 350 diameters. (*Wedl.*)

Remarks.—Emaciation occurs in almost all chronic; and in many acute diseases. It is especially marked before death by tuberculosis and by dropsy. In some cases of the latter, the fat of the adipose tissue entirely disappears, except around the heart, and serum takes its place in the adipose cells, as has been explained. It is, however, a singular fact that even phthisis generally produces little or no emaciation (even though the structure of the lungs is in a great measure destroyed), *provided the liver is also at the same time diseased;* especially if from stearosis, or the "nutmeg liver," as it is called. In tubercu-

Fig. 193.

Atrophied adipose tissue from the capsule of a gelatinous sarcoma. *a, a.* Rows of atrophied fat-globules, for the most part without any cell-membrane. *b.* Groups of normal fat-cells accompanying the above. *c.* Enlargements and bifurcate division of the elastic fibres running among the rarefied fat-cells.—Magnified 350 diameters. (*Wedl.*)

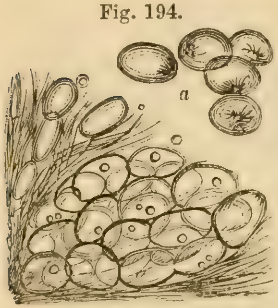
losis, also, the saponified fats are far more diminished in the blood than in any other fluid.[1] (p. 78.)

II. In case of *hypertrophy* of the adipose tissue, the cells are filled to distension with fat; and in extreme cases of its general hypertrophy—as those mentioned on page 300—new cells are doubtless formed in great numbers, together with an extension of the vessels, and the matrix of areolar tissue; in other words, there is a new formation of this tissue. In those cases, also, the accumulation interferes with the action of the muscles, and the general nutrition is impeded. Occurring in infants at the breast, it produces an impoverishment of the blood, frequently causing death rapidly and unexpectedly. (*Engel.*)

The hypertrophied fat occurring in drunkards is soft, unctuous, of a grayish-white color and mawkish smell; and it not unfrequently presents similar characters in persons who have been cured of secondary syphilis. In cancerous deposits, especially in the skin and subcutaneous areolar tissue, abundant deposits of firm, granular, deep-yellow fat also obtain. (*Engel.*)

III. The adipose tumor (Lipoma) is to be regarded as a new formation of the adipose tissue. So, also, are various forms of Steatoma. If entirely removed in these cases, it is not reproduced. In the Lipoma, some of the fat-cells may be of enormous size (even $\frac{1}{136}$ of an inch or more in diameter), mixed with others of the normal size. As the new formations of fat-cells never take place without that of the areolar tissue, the density of a fatty tumor depends upon the relative amount of the latter. (Fig. 194.) When the fat-cells are gradually replaced by a fibrous tissue, a lardaceous growth (Steatoma) is produced.

Fig. 194.



Structure of a fatty tumor (*Lipoma*) removed from the back. *a*. Isolated cells, showing the crystalline nucleus, margaric acid. (*Bennett.*)

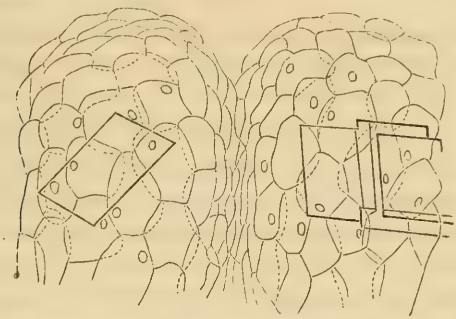
Fat-cells are also met with imbedded in other tumors, as in polypus uteri, throughout which they are sometimes disseminated. The *Lipoma arborescens* (*J. Müller*), rather frequently occurring in the knee-joint, is to be regarded as a new formation of fat-cells in addition to those normally existing in the adipose ligament, so called, of that articulation.

Encysted tumors are also found containing fat, but in the form of globules and granules, and not in cells. These are, therefore, not modifications of adipose tissue. The Cholesteatoma (*J. Müller*) is the most common. Here the cyst or sac is lined with a delicate epithelium, and filled with concentric laminæ consisting of strata of cells resembling those of sheep's fat

[1] Becquerel and Rodier.

(though only one-half as large in diameter); and between which laminæ, crystals of cholesterine are found in abundance.

Fig. 195.



Cholesteatoma of the brain, consisting of layers of epidermis-like cells, mostly with a parietal nucleus. Cholesterine plates are disseminated among the layers of the cells.—Magnified 350 diameters. (*Wedl.*)

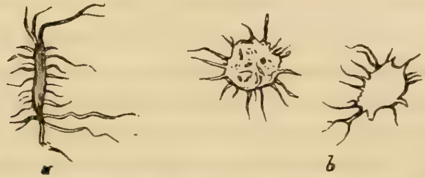
Fatty Degeneration, or Stearosis.

The phrase "fatty degeneration" suggests the idea that certain parts or organs have been converted into fat, or into adipose tissue. Neither of these ideas is, however, correct. An organ in a state of fatty degeneration is one, some or all of whose structural elements have been *replaced by fat, in the form of globules or granules*, and not inclosed in fat-cells. (Fig. 40.) This subject has, therefore, no histological connection with the adipose tissue; but it is introduced here to insure a correct understanding of it, as contrasted with the pathological formations of adipose tissue.

Fatty degeneration, or stearosis, most frequently occurs in the following organs:—

1. In the *bones*, stearosis is usually inaptly termed *osteomalacia*, or mollities ossium.[1] In this disease the osseous matter disappears, and the interstices thus formed are filled with fat-globules; and, on maceration, the bone seems to consist of a mere gauze-like tissue. The lacunæ also become enlarged, and the pores less distinct. Fig. 196

Fig. 196.



a. Lacuna and pores of bone in the normal state. *b.* Enlarged as in mollities ossium. (*Dalrymple.*)

[1] Mollities ossium may also result from other diseases; *e. g.* from cancer of bone.

shows their appearance as compared with the normal state. In an extreme case of mollities ossium, Lehmann found in the ribs the following elements, in 100 parts:—

Fat	56.92
Other organic matters	24.665
Phosphate of lime	15.881
Carbonate of lime	2.534

2. In fatty degeneration of the *heart*, only one or two fat-globules at first appear within the myolemma of the fibres; but, finally, in some cases the whole fibre is occupied by them. Then the fibres become fused together into a more or less opaque mass, in which nothing of the original tissue can be traced. Fig. 259 shows the incipient and the most advanced stage of this disease.

An accumulation of the fat-cells naturally existing under the pericardium and in contact with the heart, especially if it also insinuates itself somewhat between the muscular fasciculi and fibres, is often mistaken for fatty degeneration. But the microscope shows the fat to be in the ordinary fat-cells, and of the average size of $\frac{1}{500}$ of an inch in diameter; while in true stearosis, the fat-drops vary from a mere microscopic point to $\frac{1}{5000}$ of an inch in diameter, and are contained within the myolemmata.

3. In case of stearosis of paralyzed muscles also, the change just mentioned occurs; oil-globules being contained within the myolemmata (instead of the fibrillæ hereafter to be described), and the striæ having disappeared.

But stearosis also occurs in smooth muscular fibre, at least in that of the uterus during its atrophy after parturition. Here, also, as Kölliker has demonstrated, the fibre-cells become gradually filled with fat-drops; after which some entirely disappear, while others are reduced to their size previously to gestation.

4. In fatty degeneration of the *kidney*, the fat-drops exist partly in the epithelial cells of this organ, and partly in a free state among them. The disease affects the cortical substance more especially. Sometimes the epithelial cells are found detached, and the uriniferous tubes entirely filled with fluid fat.

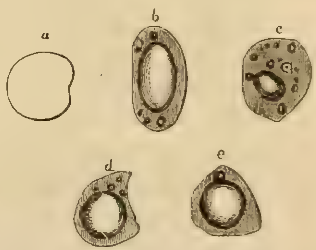
Oppoltzer conjectured that the urine contains fat whenever there is stearosis of the kidney; which, if correct, would prove a great aid in diagnosis. Lehmann, however, never found fat in the urine in this disease, except in a single instance. The fat globules sometimes seen in the urine of women, frequently proceed from the

external genitals. They are sometimes, but not invariably found in the urine during slow fevers.

It should be borne in mind that the human kidney naturally contains a small quantity of fat. (*Frerichs.*) Prof. Beale[1] has also shown that in diabetes the kidney is in a state of comparative stearosis—or increase of fat. The normal amount of fat being 3.98 parts out of 100 of the solid matter of the kidney, from three to five times as much was found in the diabetic kidney; and rather more than six times as much (26.97) in a case of actual stearosis. On the other hand, the liver in diabetes contains only from about one-third to one-half of its normal amount of fat. It is thus in a state opposed to fatty degeneration.

5. The cells of the *liver* naturally contain a few minute oil-drops imbedded in a mass of granular matter; the fat amounting, according to Prof. Beale, to from 12.15 to 15.81 out of 100 parts of the *solid* matter in this organ. In *fatty degeneration*, the cells are filled to the extent of one-half or two thirds; and are sometimes completely engaged with colorless fluid oil; the whole liver in some cases containing but 24.93 per cent. of water, and 75.07 of solid matter—of which latter 65.19 per cent. is fatty matter. A yellow matter is also sometimes seen mixed with the oil. The nuclei of the cells disappear, and the cell-wall sometimes becomes thickened and striated. In advanced cases, the cells are found even to be broken up and lost, and their place is occupied by granules, among which are multitudes of oil-drops of various sizes. (Fig. 197.)

Fig. 197.



Fatty degeneration of the liver. *a.* Empty ruptured cell from which the oil has escaped. *b, c, d, e.* Hepatic cells containing much oil.

The cells being enlarged by the increased amount of oil, the whole liver undergoes an increase of size, and the minute vessels being pressed by the development of the cells, it also becomes paler than usual. It also is found to secrete less sugar, though the amount or quality of the bile seems not to be essentially modified, as a constant result.

There is reason for the belief that fatty degeneration of the liver

[1] British and Foreign Medico-Chirurgical Review, vol. xii. p. 226.

may be produced by an excess of fatty elements in the food; especially if combined with inactive habits. This state of the organ is directly produced in fowls, by keeping them quiet (hence a dark place is better), and cramming them with oily food; as in producing the livers, of which to make the *paté de foie gras.* No such connection is, however, known to exist between the food and fatty degeneration of the other organs mentioned.

6. Something very analogous to fatty degeneration also occurs in arteries; being termed *atheroma.* It is a deposit in the middle coat of the artery, and visible through the inner coat, of a pulpy diffluent substance, and which has sometimes, therefore, been mistaken for pus. Some authors maintain, on insufficient grounds, it is believed, that fibrine merely, is first deposited in consequence of arteritis; and that atheroma is merely a fatty degeneration of the fibrine, and not of the arterial coat itself. It consists principally of fat-drops with crystals of cholesterine. Figs. 198 and 199 show

Fig. 198.

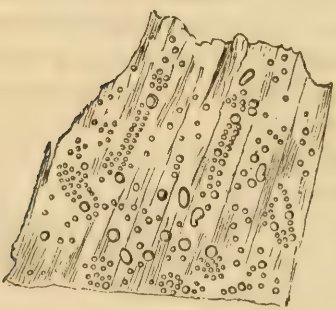


Fig. 199.

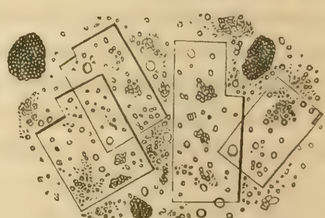


Fig. 198. Early stage of atheroma.

Fig. 199. Fatty granules with crystals of cholesterine from atheromatous deposits in the aorta. (*Bennett.*)

its appearance in the early and in the advanced stage. It conforms to the law of symmetry in a remarkable degree; occurring generally in the two arteries of the same name at the same time, *e. g.* the two iliacs, and the carotids. It is most common in the aorta, and the divisions of it nearest the heart.

7. Fat abounds in encephaloid cancer; being here also in the form of drops.

CHAPTER VI.

CARTILAGE.

Cartilage is sometimes a simple, but generally a compound tissue. It is described here more especially because of the advantage of a knowledge of the structure of cartilage as preliminary to that of the development of bone.

Cartilage is a solid, elastic, bluish, milk-white, or yellowish substance, presenting two varieties:—

1. Simple cellular cartilage.
2. Compound cartilage; consisting of cells and a homogeneous intercellular substance.

1. Very few instances of the *simple cellular* cartilage, or cartilage without interstitial substance, occur in the adult mammal. To this class, however, belong the chorda dorsalis of the human embryo, and of many adult fishes. Many, indeed, of the fœtal cartilages are merely cellular; as are also the gill laminæ of fishes in part, and those of the external ear of many mammalia. Fig. 200 shows the cells of the chorda dorsalis of the lamprey, and Fig. 201, the cellular cartilage of the mouse's ear.

Fig. 200.

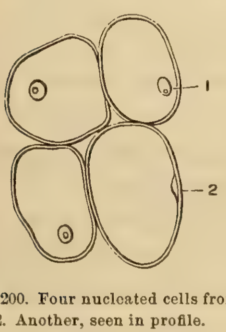


Fig. 201.

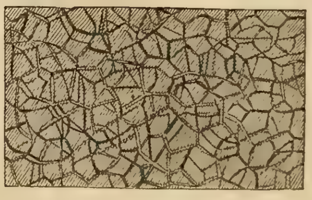


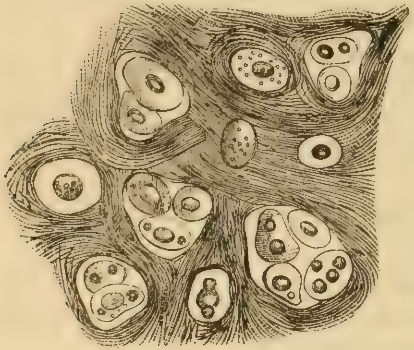
Fig. 200. Four nucleated cells from the chorda dorsalis of the lamprey. 1. Nucleus with nucleolus. 2. Another, seen in profile.

Fig. 201. Cellular cartilage of mouse's ear.

2. The *compound cartilages* (those with intercellular substance), are of two kinds: 1. *True cartilage* (or hyaline cartilage), the intercellular substance being homogeneous, and yielding chondrine on

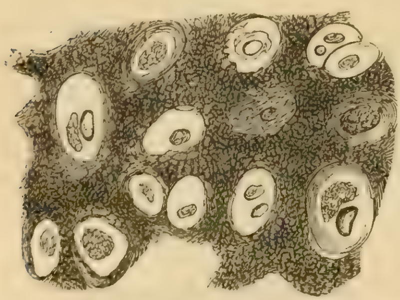
boiling. 2. Those with a fibrous intercellular substance; either white fibrous tissue, or elastic tissue. The latter are termed *fibro-cartilage*, in case the intercellular substance is white fibrous tissue (Fig. 202); and *reticular cartilage* (or yellow cartilage), if it be the elastic tissue. This last form of fibro-cartilage is found in the external ear, and the cartilaginous portion of the Eustachian tube, and in the epiglottis. The cartilages of Santorini and Wrisberg (of the larynx), and that on the condyle of the lower jaw, are of this class. The structure of the reticulated cartilage is shown by Fig. 203. Hoppe found that the reticulated cartilages yield chondrine in small quantity on boiling. He, however, maintains that this substance is not derived from the cells, nor from the elastic fibres, but from a third (a chondrine yielding) substance, surrounding the cells. Indeed, from his conclusions in regard to cartilage-cells, he was led to the axiom that cell-membranes and cell-contents never consist of gelatigenous substance (osteine or cartilageine); and can never be metamorphosed into it.

Fig. 202.



Section of fibro-cartilage; showing disposition of cartilage-cells in areolæ of white fibrous tissue.

Fig. 203.



Reticulated cartilage; human epiglottis.—Magnified 350 diameters. (*Kölliker.*)

Fibro-cartilage yields only glutin, since the white fibrous tissue constitutes its intercellular substance. All the intra-articular fibro-cartilages are of this kind. Its structure has been shown by Fig. 202.

True Hyaline Cartilage.

True cartilage consists of (1), cartilage-cells, and (2) a hyaline (or usually granular) homogeneous substance (p. 108).

The relative amount of these two elements varies much in different cartilages; either element alone also sometimes constituting almost the whole mass.

1. Cartilage-*cells* present no peculiarities in form, being rounded or elongated, flattened, or fusiform, and very rarely stellate, as in enchondroma, and in cuttle-fishes and sharks. From 1 to 4 (or even 20 to 30) cells exist together in a single cavity[1] in the intercellular substance; and sometimes they are arranged in regular rows, as in cartilages in which bone is about to be developed. (Fig. 225.)

The *cell-walls* are usually thick, and frequently are invested by concentric laminæ. They are not dissolved by boiling, and long resist alkalies and acids; thus resembling the elastic but not the collagenous tissue (p. 282).

The *contents* are clear and fluid; in which, generally, but not always, one or many fat-globules are contained. They coagulate in water and dilute acids, and are readily dissolved by alkalies. Sometimes the fat-globules are so numerous as to render the nucleus invisible. But a single nucleus is contained in each cell.

2. The *intercellular* (or interstitial) *homogeneous substance* is sometimes hyaline, but generally finely granulated. It is permeated by a peculiar fluid which has not yet been investigated. (*Lehmann.*) Fat-globules are also often found in it.

Finally, the permanent cartilages are invested by a fibrous membrane, the *perichondrium* (*e. g.* costal cartilage). This is less vascular than the analogous sheath of the bones—the periosteum, (p. 279, 4.)

Chemical Composition of true Cartilage.

The chemical characters of cartilage are, in some respects, very little known. It is certain, however, that the cells and the intercellular substance are different. The latter is converted, partially at least,[2] by boiling into *chondrine*, in case of the true cartilages, and is itself *cartilageine*, as has already been seen (p. 99). In reticulated cartilage chondrine exists in small amount (*Hoppe*), and probably also elasticine (p. 100).

[1] Kölliker and others term these cavities the *cartilage-cells*, and the true cells just described, the *secondary* cells or nuclei. We adopt Robin's view as the correct one.

[2] Lehmann infers from its behavior towards concentrated sulphuric acid that the intercellular substance contains three different, though allied substances.

What are the precise chemical characters of the cartilage-cells and their contents, is unknown.

The amount of *water* varies in the different true cartilages between 54 and 70 per cent. (*Lehmann*); and exerts an important influence on their physical properties.

The *fat* constitutes from 2 to 5 per cent. of the dry cartilage. Mulder first proved that a small amount of *sulphur* is combined with the chondrine (cartilageine). It, therefore, probably exists in the intercellular substance alone. In the costal cartilages from 3 to 6 per cent. of mineral substances have been found, viz., phosphates of lime and magnesia, chloride of sodium, carbonate of soda, and a large amount of sulphates. The chloride of sodium varies extremely in the *ash* of cartilage (from 1 to 8 per cent.); there, however, being more of it in cartilage than in any other tissue. (*Lehmann.*) These variations suggest the idea that it is combined not with the histological elements of the cartilage, but exists in the peculiar fluid which permeates the intercellular substance.

Properties and Uses of Cartilage.

True cartilage manifests only *physical*, and no vital properties, in the organs of which it forms a part; viz., solidity and elasticity. When fully developed, cartilages contain no vessels at all; and hence constitute an extra-vascular tissue, like the cornea and epithelium and its modifications (p. 281). Nor do they contain lymphatics or nerves.[1]

Uses.—The uses of the true cartilages depend on the two properties just noticed. Hence they are found where a tissue is required to resist pressure, as in the articular cartilages; whose elasticity and insensibility (from possessing no nerves) are at the same time put into requisition. The costal cartilages afford sufficient strength for the walls of the thorax, while their flexibility and elasticity favor the movements of respiration. The cartilages of the nose afford to that organ the requisite firmness and flexibility.

Finally, cartilages exist in the embryo instead of bones; and which finally assume the form of the bones to be subsequently developed. These subsequently giving place to the bones, and thus disappearing, are termed *temporary* cartilages, and in their aggregate, constitute the cartilaginous skeleton; while the others in the

[1] In the septum narium of the *calf*, Kölliker found both arteries, and small nervous twigs. The costal cartilages also contain a few vessels.

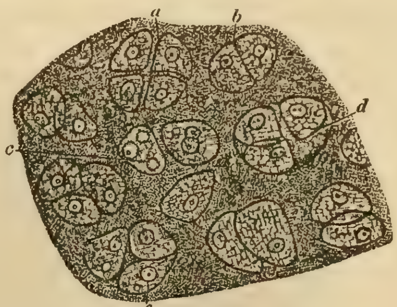
body are, in contradistinction from these, called *permanent* cartilages—*e. g.* articular cartilages, costal cartilages, &c.

Development of Cartilage.

True cartilage originates in cells not distinguishable at first from those from which the other tissues are developed. Between these cells a hyaline substance is deposited, which, on being boiled, becomes chondrine; and which usually increases simultaneously with the bulk of the cells. Thus, the original cells are pushed further and further asunder.

But new cells are also produced from germs in the hyaline substance; while at the same time the original ones are multiplied by bipartite and tripartite subdivision (p. 126). Thus, it is very common to meet with groups of two, three, or four cells (or more) in a single cavity, as shown by Fig. 204.

Fig. 204.



Section of the branchial cartilage of tadpole. *a.* Group of four cells, separating from each other. *b.* Pair of cells in apposition. *c, c.* Nuclei of cartilage-cells. *d.* Cavity containing three cells.

If the intercellular substance consist of collagenous fibres, a *fibro-cartilage* results. And sometimes the cells entirely disappear, and the whole remaining mass is fibrous. The fibres are developed in the external portions first. When elastic fibres are developed from the intercellular substance, a *reticulated* cartilage results.

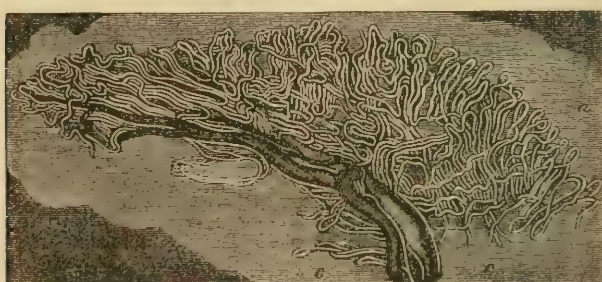
The *growth* of cartilage is secured both by the reduplication of the cells, and the increase of the intercellular substance. The plasma doubtless permeates the intercellular substance, and the peculiar fluid, before alluded to, is probably a modified plasma, and contains the elements for the nutrition of the cartilage. The cartilage-cavities of the new-born infant are three or four times as numerous as in the fœtus of four months; but the intercellular substance is now double the bulk of the cavities, while at the latter period it hardly exceeds the latter—at least in the costal cartilages. After birth, the cavities (and contained cells) and the intercellular substance, increase in pretty nearly an equal ratio. According to Harting, the cavities (and contents) are 8 to 12 times larger in the adult than in the infant at birth.

As cartilage contains no vessels, very slight nutritive changes probably occur, after it once attains to its full development.

Cartilage, if removed, is never *regenerated.* White fibrous tissue is developed instead, to fill up the breach; or a cretification of the entire cartilage may take place. (*Dr. Redfern.*) The costal cartilages, if fractured, are, however, repaired by osseous union. These cartilages are normally ossified in some of the lower animals, and are not seldom ossified in the latter period of life, in the human subject.

Articular cartilages are, in the fœtus, covered by an epithelium. This appears to be destroyed after birth by pressure and attrition. While it exists, vessels are found between it and the cartilage; and which subsequently return to the circumference of the latter. Their appearance before and after birth is shown by Figs. 205 and 206.

Fig. 205.



Vessels situated between the attached synovial membrane and the articular cartilage, at the point where the ligamentum teres is inserted in the head of the os femoris. Human fœtus between 3 and 4 months. *a.* The surface of the articular cartilage. *b.* The vessels between the articular cartilage and the epithelial layer. *c.* The surface to which the ligamentum teres was attached. *d.* The vein. *e.* The artery.

Their connection with the bones will be explained in the following chapter.

Fig. 206.

Vessels with varicose dilatations surrounding the edges of the articular cartilages, after birth.

In the *costal* cartilages, vascular canals are found at large distances from each other, and which are lined by prolongations of their perichondrium, and narrow cartilage-cells. The vessels, however, nowhere pass from the walls of those canals into the substance of the car-

tilage, and they usually do not anastomose with each other. Similar canals are also seen in the temporary cartilages near the points where the process of ossification is going on.

The changes undergone by the *cartilaginous skeleton*, will be specified under the head of the development of bone.

Pathological States, and New Formations of Cartilage.

1. As cartilage normally contains no vessels, nor passages for the circulation of plasma (like bone and the cornea), it can hardly be regarded as capable of being attacked by inflammation. It is, however, susceptible of *ulceration*, or a gradual removal of its substance, and in this condition appears to become vascular on the eroded surface. The vessels are, however, not in the substance of the cartilage, but in a membranous expansion which is formed *de novo* on its rough surface.

2. The *loose cartilages*, so called, which are often found in joints (especially the knee-joint), are not actual cartilages, but merely the non-vascular processes of the synovial membrane, which increase in size and solidity and then become detached from the vascular folds. Sometimes, however, they are mere fibrinous exudations, or solidified deposits from the synovia, as Virchow has shown.

3. A new formation of cartilage constitutes *enchondroma*. It occurs in bone more frequently than in any another normal tissue. The bones of the fingers and toes are most liable to it, though the ribs, sternum, and vertebræ are not exempt; and the cranium, the ilium, and the long bones have been attacked by it.

Enchondroma may originate on the surface of bone, or in the

Fig. 207.

Fig. 208.

Fig. 209.

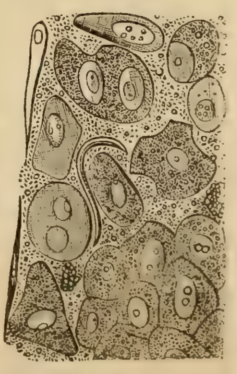
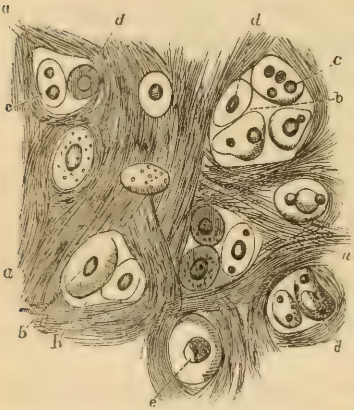


Fig. 207. Thin section of the circumference of an enchondroma from the pelvis.
Fig. 208. Cells from the softened part of the same tumor.
Fig. 209. The same, after the addition of acetic acid. (*Bennett.*)

cancellated tissue. It usually grows slowly and seldom exceeds an orange in size. It is not attended by pain or disorganization of the

surrounding parts. It, however, sometimes ulcerates and pours out an exhausting discharge.—When externally situated, it is lobulated and surrounded by an expansion of the periosteum. When internal, it presents a semi-elastic feel, and, on section, the knife passes through a thin crackling shell of bone, and then shows a white cartilaginous mass; which on microscopic examination, sometimes cannot be distinguished from true cartilage, and at others resembles fibro-cartilage. Figs. 207, 208, and 209 show the structure of the first variety; and Fig. 210, that which resembles fibro-cartilage. The former yields *chondrine* on boiling, and the latter glutin. The external variety has no investment of bone, and is met with chiefly in the pelvis, cranium, and ribs.

Fig. 210.



Enchondroma; microscopic structure. (*After Lebert.*)

Enchondroma generally, but not always, manifests no disposition to ossification. It is chiefly met with in early life, and Müller has shown that it is generally due to mechanical injury interfering with the development of bone at the period when ossification occurs and bone is formed; and the process usually commences at the point of attachment of the growth to the bone on which it is developed. When completely ossified, the enchondroma becomes an *exostosis*.

4. *Atrophy* of cartilage is not uncommon. Here the hyaline intercellular substance, especially in case of the articular cartilages, is replaced by a soft ligamentous or fibrous structure, easily scraped by the knife, and of a dirty brownish-yellow color, the fibres disappearing under the action of acetic acid. The cartilage-cells become, at the same time, more or less filled with fat-globules. The intervertebral cartilages of aged persons are usually of a dusky color, and dry; the intercellular substance being also fibrous, and containing pigment-cells. Atrophy of the articular cartilages may be produced by cancer or sarcoma, when occurring near them in the extremities of the bones.

5. *Necrosis* (or death) of cartilage occurs—as in the cartilage of the larynx—from inflammation of the perichondrium (perichondritis—*Albers*). A formation of pus in the cancelli of the articular extremities of bone, often produces necrosis of the articular cartilages.

6. Cartilage is liable to *fatty degeneration*, this affecting both the cells and the intercellular substance; both losing their transparency, and ultimately becoming wholly unrecognizable. Suppuration in the contiguous bone sometimes produces this effect.

CHAPTER VII.

OSSEOUS TISSUE, AND THE BONES.

OSSEOUS tissue is peculiar to the bones and teeth, and will be first described; after which the structure of the bones, consisting as they do of the osseous and several other tissues blended together, will be specified.

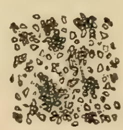
SECTION I.

OSSEOUS TISSUE.

To the naked eye the bones present two forms of the osseous tissue—viz., the *compact*, and the cancellated or spongy. But, however important these distinctions are in a practical point of view, microscopic examination shows them to be essentially identical, as will be seen.

The ultimate histological element of the osseous tissue is a pale, oval, oblong, or angular granule, $\frac{1}{6000}$ of an inch in diameter.[1] (*Kölliker.*) These granules (Fig. 211) are blended together so as to form membraniform expansions of varying thickness (the lamellæ), or irregular masses inclosing cavities of a peculiar form (the lacunæ and pores); and from the different conformations and arrangements of these lamellæ and masses, result the compact and the cancellated bone-substance already mentioned.

Fig. 211.



Ultimate granules of bone, isolated, and in small masses; from the femur.—Magnified 320 diameters. (*Tomes.*)

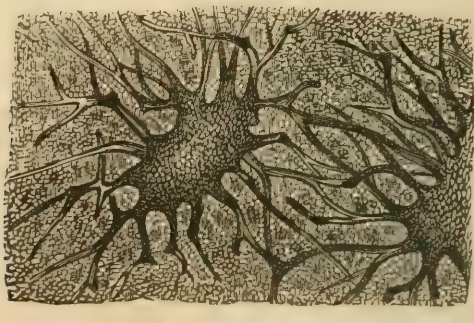
The thinnest lamellæ or a *simple plate* of bone is formed by the apposition at their margins of a single stratum of granules. It must be remembered, however, that the osseous tissue is not always granular. It is sometimes a perfectly clear hyaline substance. This form appears to be a more recent and less perfect development than the granular; and both often appear in the same bone, and even in the same lamella of an

[1] $\frac{1}{6000}$ to $\frac{1}{14000}$ of an inch. (*Todd and Bowman.*) One-sixth to one fifth the diameter of the blood-corpuscles. (*Tomes.*)

Haversian rod. In the latter case the lamina is seen to consist of two distinct layers—an external granular, and an internal, hyaline.

As a general rule, no particle of osseous tissue is found more than $\frac{1}{170}$ of an inch from a bloodvessel. If, therefore, a plate of bone be not more than double this thickness ($\frac{1}{85}$ of an inch), no vessels will be found to enter it; but they will be distributed upon its two surfaces only. It is, however, indispensable for the nutrition of bone that the plasma be brought more nearly than this to each molecule of the osseous tissue; and for this purpose cavities of a peculiar form (lacunæ and pores) are hollowed out in the substance of all but the thinnest laminæ of bone, whose forms are shown by Fig. 212. In some of the thinnest bones of the smallest

Fig. 212.



Two lacunæ of osseous tissue seen on the surface, showing the disposition of their pores. The ultimate granules of the tissue, both on their walls and around them, are well represented. (Magnified 1,200 diameters.) From the cancelli of the femur. (*Tomes.*)

animals, however—as the os unguis of the mouse and certain small birds—even these cavities do not exist; every molecule of the osseous tissue being so near to the blood in the vessels distributed upon the surfaces of the bone, that no arrangement for the transmission of the plasma alone, as before mentioned, is required. Such a bone is therefore everywhere granular and homogeneous in structure, like the portions between the pores in Fig. 212.

If, therefore, a layer of bone is not more than $\frac{1}{5000}$ to $\frac{1}{4000}$ of an inch thick, the substance is solid; if another layer be superimposed upon this, cavities for the plasma (lacunæ and pores) are formed between them, or in their substance; and if the whole thickness be more than $\frac{1}{85}$ of an inch, vessels also (the Haversian vessels) are found in canals traversing it. These cavities and canals will be next described.

1. *The Lacunæ and Pores of Osseous Tissue.*

The *lacunæ* (or bone-corpuscles) in man vary but little in size and shape. Most of them are shaped like a melon-seed; though some are more fusiform, or even spherical. Their length averages $\frac{1}{1200}$ to $\frac{1}{860}$ of an inch; some are, however, as short as $\frac{1}{2000}$ of an inch, and some as long as $\frac{1}{500}$ of an inch. They are $\frac{1}{4000}$ to $\frac{1}{1500}$, or even $\frac{1}{1200}$ of an inch broad; and from $\frac{1}{6000}$ to $\frac{1}{3000}$ of an inch thick or deep. Their three dimensions are usually as 6 : 2 : 1. The spherical lacunæ are from $\frac{1}{2000}$ to $\frac{1}{1500}$ of an inch in diameter. They are placed so near together that 709 to 1120 (average 910) occur within a surface of $\frac{1}{25}$ of an inch square. (*Harting.*)

The *pores*, or canaliculi, average $\frac{1}{1500}$ to $\frac{1}{750}$ of an inch in length, the highest extreme being $\frac{1}{500}$ of an inch. They are $\frac{1}{15000}$ to $\frac{1}{12000}$ of an inch in diameter at their origin from the lacunæ, and $\frac{1}{60000}$ to $\frac{1}{40000}$ at their finest extremities—the average being about $\frac{1}{30000}$. In horizontal sections of the lacunæ they appear as holes $\frac{1}{15000}$ to $\frac{1}{6000}$ of an inch apart. In transverse sections they produce the radiating striæ from being viewed in several planes, and appear to be somewhat closer together—or $\frac{1}{15000}$ to $\frac{1}{10000}$ of an inch apart. The canaliculi radiate from the lacunæ in *all* directions; and are branched and irregular, and often curved, in their course. A lacuna, therefore, together with its radiating pores, forms an imperfect sphere, $\frac{1}{600}$ to $\frac{1}{350}$ of an inch in diameter. The pores of the different lacunæ anastomose freely with each other, and two thus connected sometimes measure $\frac{1}{300}$ to $\frac{1}{270}$ of an inch in length. They terminate in cœcal extremities only on limited spots; the most external, opening on the surface of the bone (except when this is covered by cartilage or the insertion of ligaments and tendons), as shown by Fig. 213. Thus the entire structure of the bones is everywhere penetrated by a connected system of cavities and pores, by which the nutritive fluid from the vessels is carried to every part.

Fig. 213.

Portion of the surface of the tibia of the calf, seen on the external aspect. The numerous points are the openings of the pores; the dark, larger, indistinct spots indicate the lacunæ to which these pores belong, appearing from a greater depth.—Magnified 360 diameters. (*Kölliker.*)

Tomes and De Morgan (with Virchow, and more recently Hoppe) assert that the lacunæ and pores have distinct walls,[1] as is the case with the dentinal tubuli. Like the latter, they are also sometimes filled up with a solid matter, so as to leave only a small space in the centre. These observers also found a modification of the lacunæ in the circumferential laminæ of bones; they there being elongated tubes, and passing, in bundles or singly, more or less obliquely, from the surface towards the interior of the bone. The largest are sometimes bent once or twice at a sharp angle. They have distinct walls, and are connected laterally with the pores.

The *contents* of the lacunæ are—*first*, a nucleus; and, *secondly*, a clear fluid; thus resembling the contents of cartilage-cavities. (*Kölliker.*) Their relation to the cartilage-cells will be explained under the head of "Development of Bone." The fluid is doubtless the nutritive fluid of the bone, and is therefore plasma, or a modification of it.

The lacunæ and pores do not present precisely the same conditions in the compact and the cancellated substance of bone, as will be shown (pp. 328 and 330).

2. *The Vascular Canals of Osseous Tissue.*

The vascular or Haversian canals are minute tubular passages in the bone-substance, averaging $\frac{1}{1200}$ to $\frac{1}{240}$ of an inch (the extremes being $\frac{1}{3000}$ and $\frac{1}{66}$); and which exist everywhere in the compact bone-substance, except in the thinnest layers of it, forming a network similar to that of the capillaries in the soft tissues.

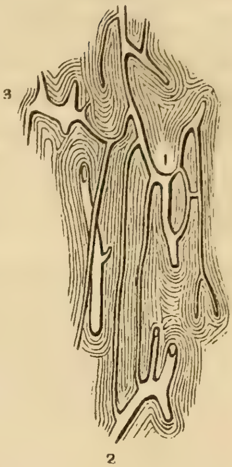
In the *long bones*, and in the ribs, clavicle, os pubis, and ischium, they chiefly run parallel to the long axis of the bone; and almost always either parallel to the surface, or perpendicular to it, and from $\frac{1}{200}$ to $\frac{1}{85}$ of an inch apart. These are, however, connected by transverse or oblique branches. Thus they form a network consisting of elongated and generally rectangular meshes, as seen in the longitudinal section of a long bone, Fig. 214. Few transverse communicating canals occur, however, in fœtal and still undeveloped bones.

In the *flat* bones, almost all the Haversian canals run parallel to their surface, and sometimes, indeed, in lines radiating from one point (as the parietal protuberance, upper and anterior angle of the

[1] Lehmann infers, also, from Hoppe's experiments, that the lacunæ and pores are lined by an albuminous membrane, insoluble in boiling water.

scapula, articular portion of the ilium, &c.). Less frequently, however, they are parallel to each other—as in the sternum.

Fig. 214.



Haversian canals, seen on a longitudinal section of the compact tissue of the shaft of one of the long bones. 1. Arterial canal. 2. Venous canal. 3. Dilatation of another venous canal.

In the *short* bones there is usually one predominant direction for the Haversian canals; they being vertical in the vertebræ, and parallel to the long axis of the extremity, in the carpal and tarsal bones. In the spinous processes, however, as in the coracoid and styloid processes, the canals are arranged as in the shorter cylindrical bones.

Finally, a few Haversian canals exist in the walls of the *cancelli* of bone, but only when they are of considerable thickness.

Since the Haversian canals contain vessels, they open—*first*, externally on the outer surface of the bone; and, *secondly*, internally on the walls of the medullary canals and spaces. In both these positions, indeed, very many of them can be seen by the unassisted eye; they being more numerous in proportion as the compact substance of the bone is thicker. The larger passages are, however, merely for the vascular branches communicating with the proper capillary plexus in the interior of the bone-substance. Kölliker has never noticed cœcal terminations of these vascular canals. The internal network must, however, in some parts have little or no communication with vessels from the surface of the bone—as at the points of insertion of many tendons and ligaments, &c.

It should be added here that Tomes and De Morgan have described still another kind of cavities in bone, which they have named *Haversian spaces*. These are apparently formed by the absorption of previously-formed bone, between and parallel to the Haversian canals; present rough parietes, and are sometimes formed at the expense of portions of two or three of the Haversian systems or rods at the same time. After attaining their full diameter, ossification commences within them, and each of them becomes a new Haversian canal, surrounded by its concentric laminæ, and its lacunæ and pores. These cavities are very large and numerous in newly-formed bone situated near ossifying cartilage; they are, however, never absent in the oldest subject, and may be accepted as a

demonstration of the fact that bone is constantly undergoing an active disassimilation and repair. Indeed, one side of an Haversian space may be becoming the seat of a new Haversian rod of bone, while the opposite is undergoing further enlargement from absorption.

The *contents* of the Haversian canals are—*first*, the vessels; *secondly*, the nerves of bone; and, *thirdly*, in case of the larger canals, a small quantity of marrow surrounding the former.

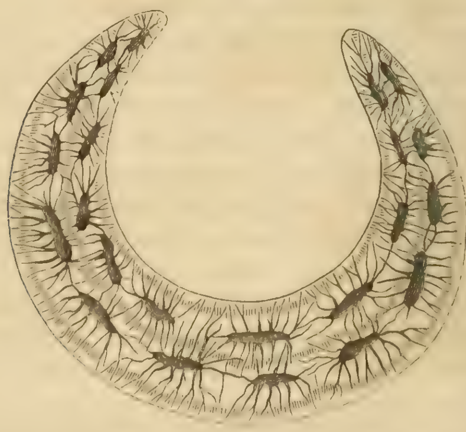
Differences in the Compact and the Cancellated Forms of Bone-structure.

All bones contain both the cancellated and the compact forms of structure; the former constituting an external layer of varying thickness, and the latter the internal portions. In the shafts of the long bones, however, the entire thickness is formed of compact bone-substance; and the same is true of the thinnest portions of some of the flat bones. The extremities of the long bones, however, like all the short bones, consist of a thin layer of compact substance externally, and cancellated substance within.

In both forms, however, the bone-tissue is arranged in the form of laminæ or plates, formed of granules or hyaline substance (or both), as already described (p. 321); and the manner in which these laminæ are arranged, determines the two forms of bone-substance now to be described.

1. *Cancellated Bone-structure.*—The cancellated bone-structure consists of an aggregation of cavities, each of which is called a *can-*

Fig. 215.

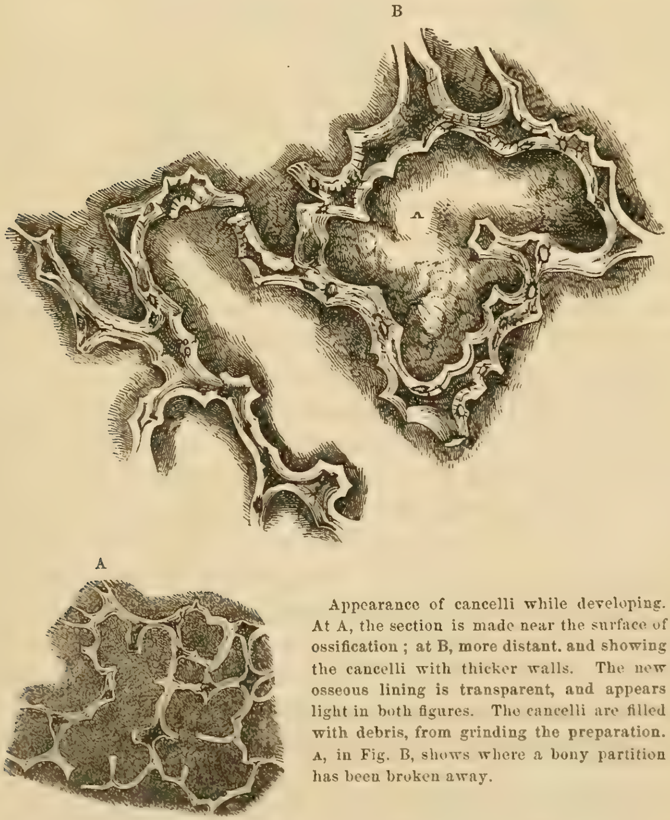


Spherical cancellus (diagrammatic). Its walls consist of three lamellæ, with their lacunæ and pores.

cellus, whose walls are formed of laminæ of osseous tissue. These cavities are quite irregular in form, and communicate freely with each other, as may be seen in a section of the short bones, or of the extremities (epiphyses) of the long ones. Indeed, their appearance is so similar to the areolæ of the sponge, that the terms *spongy*, *areolar*, or *reticulated* bone-structure are also applied to them.

The walls of the cancelli are formed of several concentric laminæ of osseous tissue, between and in the substance of which lacunæ and pores exist; and through an opening the vessels are sent into the cavity of the cancellus, to ramify upon its inner surface. If the cancellus be supposed, for the sake of simplicity, to assume a spherical form, its appearance on section will be represented by Fig. 215.

Fig. 216.



Appearance of cancelli while developing. At A, the section is made near the surface of ossification; at B, more distant, and showing the cancelli with thicker walls. The new osseous lining is transparent, and appears light in both figures. The cancelli are filled with debris, from grinding the preparation. A, in Fig. B, shows where a bony partition has been broken away.

The cancelli, however, in fact, communicate so freely with each other, that their walls lose the structural regularity there represented;

and hence this form of bone-substance seems rather to present an interlacement of lamellæ, rods, and fibres, very irregularly arranged. (Fig. 216.) If the connecting rods are of considerable size, they contain vascular canals; otherwise, merely laminæ, lacunæ, and pores. The lacunæ are disposed in every possible direction; but mostly with their long axes parallel to that of the fibres and rods, and with their flat surfaces directed towards the cancelli, into which the most superficial lacunæ freely open. The vessels of different cancelli freely anastomose with each other.

The cancelli contain—*first*, the vessels already mentioned; *secondly*, a prolongation of the periosteum or endosteum supporting these vessels; and, *thirdly*, more or less fat-cells with red contents (marrow). Nerves also, *fourthly*, are distributed to the marrow, especially in case of the bodies of the vertebræ.

2. *Compact Bone-structure.*—The thinnest layers of compact tissue consist merely of parallel superimposed lamellæ, between and in the substance of which lacunæ and pores (but no vessels) exist; *e. g.* some portions of the lachrymal and palate-bones. Indeed, the wall of a cancellus, as before described, is essentially a very thin layer of compact bone-structure.

When the compact structure, however, attains to a thickness of $\frac{1}{85}$ of an inch, and more, a different arrangement of the lamellæ is found. And in the long bones the compact substance consists of two systems of lamellæ (the general and the special), and the interstitial osseous tissue, or that between the Haversian rods.

1. The *general* (fundamental) lamellæ are parallel to the external and the internal surface of the bone. These alone exist where the compact substance is very thin. They, however, rarely entirely surround the long bones, and are absent in the fast-growing bones of young animals.[1] (*Tomes and De Morgan.*) They are in immediate connection at many points with those next to be described, and are seen in Fig. 217. The lacunæ are placed with their surfaces parallel with those of the lamellæ; their pores opening in part on the external and internal surfaces of the bone, and in part communicating with each other, though they probably terminate in blind extremities at points covered by the articular cartilages. The thickness of

[1] In these the circumferential laminæ are replaced by a series of undulating laminæ, which, subsequently extending outwards, arch over and inclose the nearest vessels of the periosteum; and in the spaces thus formed, Haversian rods are developed (p. 357).

Fig. 217.

A. Transverse section of ulna, deprived of its earth by an acid. The openings of the Haversian canals seen, natural size. A small portion is shaded, to indicate the part magnified in B B. Part of the section A, magnified 20 diameters. The fundamental or general lamellæ are seen at *a*, and between the concentric lamellæ the lacunæ appear as little dark specks. *b*. Portion of a cancellus.

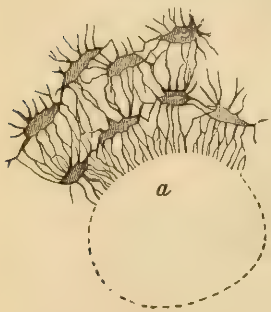
each lamella averages $\frac{1}{150}$ to $\frac{1}{75}$ of an inch in the cranial bones, and their number varies from 10 to 100. The layer formed by them varies between $\frac{1}{60}$ and $\frac{1}{30}$ of an inch in thickness. It gives off processes, $\frac{1}{600}$ to $\frac{1}{100}$ of an inch thick, between the Haversian rods.

2. The *special* lamellæ—those concentrically surrounding the Haversian canals—constitute, as it were, the walls of the latter, and are intimately united to each other. The number surrounding the canal, and the consequent thickness of the system—the *Haversian rod*—formed by them, bear no constant relation to the size of the canal; smaller canals being sometimes surrounded by numerous lamellæ, and larger ones by but few. Generally the largest canals, and the most minute, have but few surrounding lamellæ, and therefore have thin walls; while those of a middle size have thick ones. The thinnest walls measure $\frac{1}{1500}$ to $\frac{1}{600}$ of an inch, and the thickest $\frac{1}{150}$ to $\frac{1}{120}$ of an inch. (*Kölliker.*) Each lamella is from $\frac{1}{6000}$ to $\frac{1}{2400}$ of an inch thick, averaging from $\frac{1}{4000}$ to $\frac{1}{3000}$ of an inch.

They frequently present two distinct layers; the outer being distinctly granular, the inner clear and transparent. The innermost lamella of an Haversian rod is, however, sometimes transparent throughout. The number of lamellæ in each Haversian rod is usually from 8 to 15; but sometimes there are only 4 or 5, and occasionally as many as 18 to 22. The whole Haversian rod averages about $\frac{1}{120}$ of an inch in diameter.

Between and in the substance of the lamellæ, the lacunæ and pores exist. The lacunæ have their long diameter curved so as to lie concentrically with the lamellæ in a transverse section of the Haversian rods, their flat surface presenting towards the Haversian canal. Their very numerous pores produce a very close striation radiating from the Haversian canals, as shown by Fig. 218. The lacunæ are sometimes very numerous, at others very scanty. In the former case, they are generally arranged in tolerably regular alternation, or one behind another in the direction of the radius of the Haversian rod. Frequently, however, they are very irregularly crowded together, or are separated by wider interspaces.

Fig. 218.



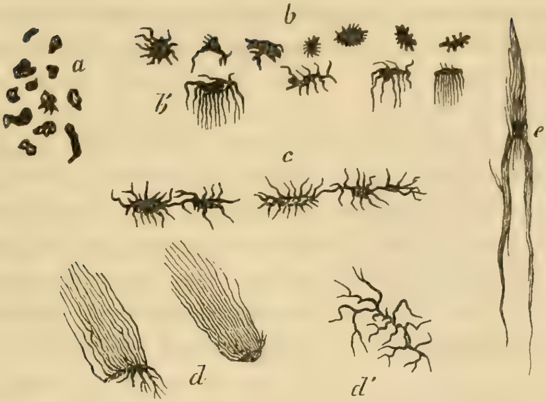
Transverse section of a part of the bone surrounding an Haversian canal; showing the pores commencing at the inner surface, *a*, anastomosing and passing from lacuna to lacuna.—Magnified about 300 diameters. (*Tomes.*)

All the pores arising from the inner aspect of the innermost lacunæ penetrate into the Haversian canals. From the edges and external aspect of the same lacuna other pores are given off which communicate with the proximate pores of the more distant lacunæ, and thus the Haversian rod is completely penetrated by the pores and lacunæ, and permeated by the nutritive fluid contained in them. The various forms of lacunæ and pores are shown by Fig. 219.

The outermost lamella is often of somewhat irregular outline from its being the first formed in the pre-formed irregular Haversian space.

3. The *interstitial* osseous tissue between the Haversian rods, when it exists in small quantity, frequently presents only one to three lacunæ in a transverse section (Figs. 220 and 217), both of a rounded form and quite irregularly disposed. When more abundant, it is distinctly lamellar, and the lacunæ are more regularly dis-

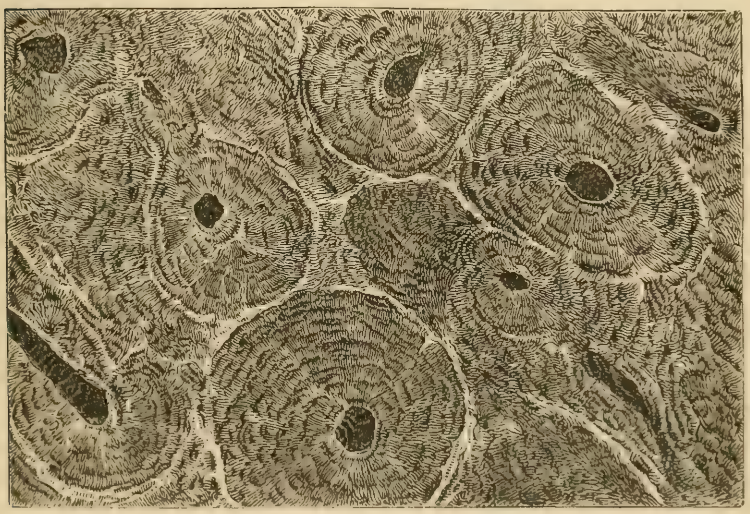
Fig. 219.



Various forms of lacunæ and their pores. *a.* Simple regular cavities without pores, from an ossification of the pleura. *b.* From healthy human bone. *b'.* One of the outer lacunæ of an Haversian system, with pores all bending down towards the Haversian canal. *c.* Other forms from human bone, showing the lateral connecting pores. *d.* From the Boa, external lacunæ of an Haversian system with unusually large pores dipping towards the vascular surface. *d'.* Cavity intermediate between a lacuna and a pore. *e.* Another variety from the same reptile. (*Mr. Tomes.*)

posed, and with their sides parallel to those of the lamellæ. The pores of these lacunæ communicate with each other, and with those of the surrounding Haversian rods, and thus their nutrition is pro

Fig. 220.



Transverse section of human clavicle, showing the orifices of the Haversian canals, and the concentric arrangement of the laminæ of bony matter and of the lacunæ around them; and the interstitial osseous substance. (Magnified 85 diameters.)

vided for. In man, however, the rods are so crowded that no lamellæ exist between them; but only the interstitial tissue with a few lacunæ (and their pores), as described in the preceding sentence. (*Kölliker.*)

Chemical Composition of Osseous Tissue.

It is almost impossible to isolate the osseous tissue completely from the vessels and nerves distributed to it; and hence there is some uncertainty in regard to its precise chemical composition.

On removing the vessels and nerves from the compact bone-structure, as far as possible, the following results are obtained by the best chemical analysis of *dried* compact osseous tissue:—

Organic substance (osteine)		33
Mineral constituents		67
Phosphate of Lime	57	
Carbonate of Lime	8	
Phosphate of Magnesia	1	
Fluoride of Calcium	1	

Osseous tissue also contains the chloride of sodium, and some alkaline sulphates and fat. The last, amounting to from one to three per cent. in some bones, must belong, in all probability, to the blood in the vessels, or to the marrow in the cavities of bone; while Lehmann believes the chloride of sodium (.25 to .38 per cent.), also, is derived probably from the vessels or the fluid in the lacunæ and pores; and the alkaline sulphates are a product of the incineration of the bone.

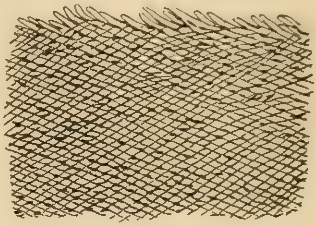
The amount of *water* in bone is about 13 per cent. (*Robin and Verdeil.*)[1] The flat bones contain more water than the cylindrical; probably because they are more vascular. Human bones contain more water than those of any other mammal (*Stark*); the bones of birds still more; and the bones of fishes most of all animals. Nasse maintains that the hardness of bones is not affected by their proportion of water; a proposition which seems untenable in respect to diseased bones at least.

The *bone-cartilage*, as Lehmann terms it, may be separated from the mineral matters by the prolonged action of dilute (1 to 7 of

[1] Dr. Stark found only three to seven per cent.

water) and frequently changed hydrochloric or nitric acid; and thus obtained, it perfectly retains the form of the bone of which it constituted a part. In its moist state, it is a tolerably elastic, yellowish, translucent substance; and in its chemical analogies it is found to coincide perfectly with glutin, except that the former has always a little sulphur which is absent in the latter. Under the microscope it shows a network of obliquely decussating fibres, as seen in Fig. 221. The bone-cartilage is, therefore, actually *osteine*, as shown on page 99. It is converted by boiling water into three or four times its volume of glutin.

Fig. 221.



Thin layer peeled off a softened bone, as it appears under a magnifying power of 400. The figure, which is intended to represent the reticular structure of the osteine of a lamella, gives a better idea of the object when held rather further off than usual from the eye.

On the other hand, the osteine may be removed from the mineral constituents by calcination, or by careful boiling in dilute alkalies. In this case, also, the *mineral* constituents alone remaining, preserve the original form of the bone.

It is probable that the phosphate and carbonate of lime are united together, before combining chemically with the osteine (*Robin and Verdeil*); and possibly the fluoride of calcium and the phosphate of magnesia are also previously combined with the two first mentioned salts. Still, the organic and mineral matters are by no means always in the same proportion in the different bones of the same person. The bones of the extremities contain more earthy matter than those of the trunk; and the humerus and femur more than the other cylindrical bones. The ribs and the clavicles contain on an average more osteine than the vertebræ; and the bones of the pelvis approximate the latter. Of the different mineral matters, the phosphate of magnesia always rises and falls with the phosphate of lime; while the ratio of the carbonate of lime to the phosphate varies,[1] though within certain not very wide limits at the same age. Lehmann found the proportion of the carbonate to the phosphate of lime in the bones of a new-born infant to be 1 : 3.8; in a male adult, 1 : 5.9; and in a man 63 years old, 1 : 8.1. In disease, however, the carbonate of lime often increases while the phosphate diminishes; and hence it has been asserted, incorrectly, that the

[1] Von Bibra asserts that these two salts are always in nearly the same ratio.

total amount of the earthy matters in bone remains constantly the same. The herbivora have more carbonate of lime in their bones than the carnivora, and the pachydermata and cetacea most of all.

The bones of fishes contain the least earthy matter of all (21 to 57 per cent.).

The varying amount of phosphate of lime in the different bones has already been stated (p. 54). The bones of birds contain more of it than those of mammals, it sometimes rising to 84.3 per cent. Carnivorous birds, however, have but little more than mammals.

In pregnancy, the consumption of phosphate of lime is so great in the development of the skeleton of the fœtus, that sometimes scarcely any traces of it can be found in the urine of the mother; and fractures now occurring, unite with extreme difficulty, and sometimes, indeed, not at all. The softened condition of the bones constituting *rickets* also most frequently occurs during dentition, while the phosphate of lime is required for the development of the teeth, the latter not being affected by this disease.

It is a singular fact that the cranial bones exhumed at Pompeii contained more fluoride of calcium than the bones of the present generation.

Doubtless the food must exert some influence on the composition of the bones. Softening of the bones occurred in chickens deprived, by Chossat, of the phosphate of lime.

There is no appreciable difference in composition of the bones of the male and the female.

Alumina, oxide of iron, and silica, are frequently found in fossil bones; their presence being probably due to infiltration.

In *diseased* bones, a great diversity of chemical composition is found. The mineral substances are, however, almost always abstracted from the osseous tissue earlier and in larger quantity (*Von Bibra*); so that a relative increase of the osteine is observed. Of the earthy matters, the phosphate of lime is the first to be removed, and the last to be re-deposited after the cessation of disease.

The osteine is very rarely affected in diseased bones. From some cases of rachitis, however, both Marchand and Lehmann failed to obtain any true glutin.

The carbonate of lime frequently exceeds its normal amount, only in osteophyte and new formations of bone. It appears usually to diminish and afterwards to increase, with the phosphate.

In *primary sclerosis* (eburnation), there is no excess of earthy matters in proportion to the osteine; but a considerable augmentation of the carbonate of lime in proportion to the phosphate.

In most *osteophytes* (puerperal or otherwise), there is an excess of osteine and carbonate of lime above the normal standard. Very likely, however, they approximate more nearly to true bone in proportion to the time since their first formation. The analyses of *exostoses* tend to the same conclusion.

In *osteoporosis* (dilatation of the cancelli and of the Haversian canals), the resorption of the mineral matters proceeds more rapidly than that of the osteine, and the cavities formed are filled with fluid fat.

In *rachitis* there is a relative deficiency of earthy matters, with an absolute excess of the osteine; the latter remaining unchanged in its nature. The assumption that the carbonate of lime is increased in rachitis is incorrect. Nor can rachitis be conditional on the occurrence of free acid in the bones, though the phosphate of lime is often much diminished.

In *softening* of bone in the adult (osteo-malacia), the earthy constituents are more diminished than in any bone disease yet mentioned. A large portion also of the osteine is destroyed. The brittle network of bony tissue remaining, floats in thin, fluid fat, sometimes amounting to twenty or thirty per cent. C. Schmidt proved the existence of free lactic acid in the fluid of the long bones. This may, however, be the result and not the cause of the breaking down of the bone into fragments—a chemical process having occurred in the latter.

In *caries*, the earthy matters most rapidly disappear, and the cavity formed is filled with fat.

Properties and Uses of the Osseous Tissue.

The characteristic properties of osseous tissue are its hardness, density, and rigidity—due to the earthy constituents; and its elasticity and flexibility, dependent upon the osteine. It manifests no vital properties, except so far as to secure its own nutrition and reparation.

The uses of the bones will be specified after their structure is described, in the second section of this chapter.

Distribution of the Osseous Tissue.

The osseous tissue is found:—

1. In the bones, of which the skeleton is composed; to which the ossicula auditus, and the os hyoides also belong.

2. In the bones developed in the tendons; as the sesamoid bones, patella, &c.

3. In the cementum of the teeth.

Many of the cartilages also ossify pretty regularly as age advances; as the costal cartilages, and those of the larynx.

Distribution in the Lower Animals.

In the *invertebrata* true osseous tissue is never found; the external calcareous skeleton taking its place.

In the other *vertebrata*, osseous tissue is more extensively distributed than in man. It exists, 1, in the *skin* (of the armadillo, tortoise, lizard, and fishes); 2, in *muscles* and tendons (the diaphragmatic bone of the camel, lama, and porcupine, and the ossified tendons of birds); 3, in the *eye* (the sclerotic ring of birds, chelonians and saurians, and the bony scales of the sclerotic of many fishes); 4, in the external portion of the *nose* (the proboscis of the pig and mole and the *os pronasale* of the sloth); 5, in the *tongue* (*os entoglossum* of fishes and birds); 6, in the *air-passages* (the laryngeal, tracheal, and bronchial bones of many birds); 7, in the *sexual organs* (penis-bone of some mammalia); 8, and as additions to the skeleton (ossa sterno-costalia of birds and some mammals).

SECTION II.

STRUCTURE OF THE BONES.

The bones are usually divided into the long,[1] the short, and the flat; and the largest bones, especially the long ones, have the following elements entering into their structure:—

1. Osseous tissue.
2. Bloodvessels.
3. Nerves.
4. Marrow (adipose tissue).

Besides, the external surface of the bones is covered at every point by some one of the following structures:—

1. Periosteum.
2. Articular cartilages, and interarticular fibro-cartilages.
3. Synovial membranes.
4. Insertions (or origins), of tendons or ligaments.

The *periosteum*[2] has already been described in general (page 279); it being the fibrous membrane which invests the bone, and in which the vessels ramify before entering the substance of the latter. A more definite description of it will be given in the order above.

[1] The long bones consist of the shaft (diaphysis) and the two extremities (epiphyses); the structure of the latter being like that of the short bones.

[2] From περὶ, around, and οστέον, a bone.

1. *The True Osseous Tissue.*

This peculiar element of the bones has been described at length (pages 321—335).

2. *The Bloodvessels of the Bones.*

The bloodvessels of the bones are first sent to the periosteum, which, besides the branches it transmits directly into the substance of the bone, presents a pretty close network of capillaries, $\frac{1}{2400}$ of an inch in diameter in its outer layer. The vessels entering the substance of the bone are very numerous.

On the long bones are distinct vessels for the nutrition of (1) the cancellated structure of the extremities, (2) of the compact substance of the shaft, and (3) of the marrow. The latter, called the *vasa nutritia*, enter the medullary cavity of the bones, one or two to the shaft, and several to the epiphyses, through large openings and canals; and, except a few twigs given off to the innermost Haversian canals of the compact substance, ramify in the marrow, where they form a capillary plexus whose vessels are from $\frac{1}{3000}$ to $\frac{1}{2350}$ of an inch in diameter.

(2.) The vessels of the compact substance rise principally from those of the periosteum. They very soon lose their muscular coat, and form in the Haversian canals (which they fill either alone or in connection with some medullary substance), a network of wide vessels. The latter can hardly be regarded as capillaries, however, since they show a layer of areolar tissue and an epithelium; and fine capillaries co-exist with the main vessel only in the larger canals.

(3.) The cancellated structure of the extremities of the long bones is supplied by the vessels transmitted by the numerous canals seen by the unaided eye upon their external surface.

The *venous* blood is returned from all the long bones in three ways: (1), by a large vein accompanying the nutrient artery, and whose ramifications it follows; (2), by numerous large and small veins at the articular extremities; and, (3), by many small veins independent of each other in the compact tissue of the shaft, in which their roots occupy the wider spaces and sinuses, or pouch-like excavations, which are very evident in sections of bone. (Fig. 214, 3.)

All the vessels of bone just mentioned freely communicate, so

that it is possible for the blood of any one part to reach any other part.

In the *short* bones, the bloodvessels present very nearly the same conditions as those of the epiphyses of the long bones; the arteries and veins of larger and smaller size entering and quitting the bone at numerous points on the surface.

In the *flat* bones, as the scapula and coxal bone, there are distinct apertures for the larger arteries and veins; the compact substance receiving finer vessels from the periosteum, and the cancellated structure being supplied by numerous and large vessels. In the flat *cranial* bones the arteries mostly enter the compact and the spongy portions (diploë) from both surfaces; while the veins have only their extremities free in the cavities of the diploë as in other bones, and their trunks contained in large, arborescent canals, emerge at definite points through large apertures (emissaria Santorini), and communicate freely with the veins of the dura mater. The veins of the cranial bones, however, become obliterated as age advances, coincidently with the diminution of the diploë. In the new-born infant, arteries as well as veins, occupy the *emissaria*. The articular cartilages have no vessels at all. Those of the synovial membranes will be described further on.

Lymphatic vessels in bone have been described by some anatomists. Kölliker, however, does not admit their existence in either bone, periosteum, or synovial membranes; though they pretty certainly exist in the loose areolar tissue around the last, especially at the knee.

3. *Nerves of the Bones.*

It is necessary to distinguish the nerves of the bones from those of the periosteum, in which the former lie, before entering the substance of the bone. The nerves of the bone are larger than those of the periosteum, and sometimes give off the latter as branches. They exist in all bones—except, perhaps, the small bones of the ear, and the sesamoid bones—though not in all bones fulfilling the same conditions. In the *large cylindrical* bones, they, *first*, penetrate into the medullary cavity with the nutrient vessels of the marrow (whether there be one or two); the trunks being visible to the naked eye, and as much as $\frac{1}{75}$ of an inch in diameter. They are distributed to the marrow, following the course of the vessels, though not always in apposition with them, towards the epiphyses; forming

many ramifications, and but few anastomoses. *Secondly*, numerous finer nerves penetrate with the numerous bloodvessels into the cancellated tissue, and ramify in the medulla. And, *thirdly*, extremely delicate nervous filaments are sent into the compact structure of the epiphyses, in company with the minute arteries by which they are penetrated. The *smaller* cylindrical bones of the hand and foot present the same conditions as the larger ones just described, except that the nerves are not so regularly divided into epiphysal and diaphysal, on account of the undeveloped condition of the medullary cavities.

Of the *short* bones, the vertebræ are most abundantly supplied with nerves; and especially their bodies. (*Kölliker.*) They enter anteriorly, posteriorly, and on the sides, in company with the vessels, and are distributed to the marrow of the spongy substance.

In the *flat* bones—as the scapulæ and coxal bones—the nerves are very numerous, and enter the bone with the larger vessels before described. In the occipital, parietal, and frontal bones, microscopic nervous filaments enter as far as to the diploë, upon the finer arteries.

The nerve-fibres thus richly distributed to bone are both cerebrospinal and sympathetic; the former constituting about two-thirds of all the fibres, and being $\frac{1}{6000}$ to $\frac{1}{3000}$ of an inch in diameter. (*Kölliker.*) The periosteal nerves are also, apparently, mainly spinal; though some participation of the sympathetic cannot, perhaps, be denied in their case, also.

How the nerves of bone terminate, is not yet decided. They sometimes have Pacinian bodies upon them just before entering the bone-substance.

The principal *function* of the nerves of bone seems to be to regulate the flow of blood and plasma through the part. (*Kölliker.*)

The synovial membranes also contain nerves. The ligaments (in man) do not; and the same is true of the articular cartilages.

4. *The Marrow of the Bones* (*Medulla*).

Almost all the larger cavities in the bones are filled by a soft, transparent, yellowish or reddish, highly vascular substance, the *marrow*. It is found chiefly in the medullary canals of cylindrical bones, and in the cancelli of all bones; though it also enters into the larger Haversian canals of the compact substance. In the shafts of the long bones it appears as a *yellow* semi-fluid substance, differing essentially in chemical composition from the *red* kind of marrow

which occurs in their epiphyses, and in the short and flat bones, the sternum, and the bodies of the vertebræ. These two forms are also quite different in chemical composition. While the former is made up (in the bones of the ox, according to Berzelius) of 96 per cent. of fat, 1 of areolar tissue, and 3 of fluid with extractive matter, the latter (in the diploë) contains 75 per cent. of water, the rest (25 per cent.) being made up of solid matters, albumen, fibrine, and extractive matter, similar to those of muscle, with merely *traces* of fat.

In its structure, marrow presents, besides vessels and nerves, areolar tissue, fat-cells, free fat, and a yellowish fluid; and, lastly, peculiar minute cells—marrow-cells.

1. The *areolar* tissue inclosing the marrow of the shaft of long bones is of a firm consistency, but is improperly described as an *endosteum* (internal periosteum), since it cannot be separated as a distinct structure. It also penetrates the marrow of the long bones, and supports the vessels and nerves; while it does not enter at all into the marrow of the cancelli, except in case of the larger masses of it.

2. *Fat-cells*, $\frac{1}{750}$ to $\frac{1}{375}$ of an inch in diameter, and often with a distinct nucleus, occur in both forms of marrow; more abundantly, however, in the yellow, dense form, and generally not aggregated into lobules. In the red variety they are far less numerous, and often isolated even; and hence the small quantity of fat in the diploë. (*Berzelius.*) In dropsical marrow, these cells are frequently only half filled with fat, or with but one or more globules; containing, besides, a large quantity of serum (p. 307). In hyperæmia of the bones, they are sometimes diminished in size, and are also elongated and fusiform.

3. *Free fat-globules*, and a clear or yellowish fluid, are often met with in the softer kinds of marrow. The former may possibly have been derived from cells which no longer exist.

Lastly, the *marrow-cells* occur in the red or the reddish marrow, but never in the yellow. They exist normally in the vertebræ, the cranial bones, the sternum, and the ribs; and in the upper maxillary bone, also, where they have been mistaken for cancer-cells. They also occur in the hyperæmiated red marrow of the articular extremities of the cylindrical bones; but are normally absent in all the bones of the extremities, and in the scapulæ and the coxal bones. They precisely resemble the cells of the young medulla (p. 355).

Use of the Marrow.—The cavities of the bones in man must be

filled either with a fluid or a solid substance, since they do not communicate with the air. The marrow being a form of adipose tissue, answers the purpose, therefore—*first*, of mere package; but, *secondly*, it also, from the fat it contains being lighter than other animal fluids, renders the bones lighter than they would be, were the latter substituted; and, *thirdly*, in the emergency of starvation, it is reabsorbed into the blood, and thus prolongs life—its cells becoming at the same time filled with a serous fluid (p. 307).

In most *birds*, the cavities of the long bones communicate indirectly with the atmosphere, and therefore contain no marrow.

The Periosteum.

The periosteum is a more or less transparent, slightly glistening, or whitish-yellow extensible membrane. It is also vascular, and invests the surface of the bones, except where certain muscles and ligaments are inserted, and where the surface is covered by the articular cartilages.

It is, however, not everywhere constituted alike. When only covered by the skin, or connected with fibrous structures (as ligaments, tendons, fasciæ, and the dura mater), it is opaque, thick, and generally glistening like tendinous structures. On the other hand, it is thin and transparent when muscular fibres rise directly from it, and when the muscles nearly rest upon the bone (as on the external surface of the cranium); also in the vertebral canal and in the orbit. When mucous membrane rests on bone, the periosteum is generally very intimately united to it by the submucous areolar tissue; so that the two cannot be separated, and constitute a single membrane of varying thickness (in the ethmoid cells, maxillary sinus, &c.).

The connection of the periosteum with the bone is sometimes very loose, it being merely in apposition, or attached by delicate vessels penetrating the bone; and sometimes very firm and intimate by means of larger vessels and nerves, and numerous tendinous filaments. The former occurs more generally where the periosteum is thin, and the osseous tissue more compact, as in the shafts of long bones and in the sinuses of the cranium; the latter, where the periosteum is thicker, and the compact substance thinner, as in the epiphyses, in the short bones, the palate, and at the base of the cranium.

In its *intimate* structure, the periosteum presents almost always, except where muscles rise from it directly, two layers, differing

more or less in structure, though closely connected. The *external* layer is composed chiefly of white fibrous tissue, with occasional fat-cells, and in this are the true vessels and nerves of the periosteum. The *inner* layer contains elastic fibres, usually of the finer sort, constituting very thick networks—true elastic membranes—superimposed one upon another. The white fibrous tissue constitutes the least important element. Nerves and vessels occur in this layer, also; but they merely pass through it, preparatory to entering the bone itself.

The following surfaces of the bones are not covered by periosteum:—

1. All surfaces where the bone is covered by the articular (or other) cartilage, or fibro-cartilage.

2. Where ligaments and tendons are attached to bones at a certain angle; *e. g.* the ligamenta subflava, ligamentum teres, ligamentum patellæ, and the intervertebral, ilio-sacral, and interosseous ligaments; and the tendons of the deltoid, the coraco-brachialis, popliteus, triceps, psoas-iliac, gastrocnemii, quadriceps femoris, glutæi, &c. On all these surfaces the structures just mentioned are attached directly to the bone, and not a trace of periosteum is found.

Articular Cartilages.

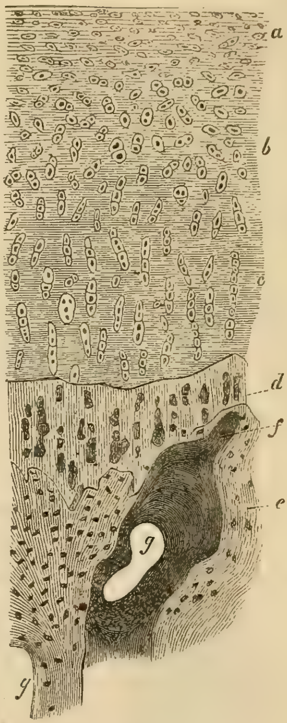
The articular cartilages cover the bones at their articular extremities. They are closely applied to the bone with a rough, hollowed, or raised surface, but are not *united* to it by any intermediate substance. On its free surface, it is in most joints quite *bare* in the adult; but covered in the fœtus by a delicate epithelium like that lining the vessels, as has been already asserted (p. 318). The *fibro-cartilages of circumference*, so called (glenoid and cotyloid ligaments, &c.), are firm, yellowish-white rings of white fibrous tissue, containing a few isolated cartilage-cells, attached at the border of the articular cartilage, by a wider base, immediately to the bone, or partly also to the cartilage. They are generally free, and not covered by the synovial membrane or any epithelium. Reichert found fine desquamated flakes of cartilage in the synovia, which fell readily into folds, and thus resembled a fibro-cartilaginous tissue.

In its *intimate* structure, articular cartilage is peculiar only in the fact that the cartilage-cavities near the free surface are small, numerous, flattened, and parallel to it; while those in the deeper portions next to the bone are elongated, and arranged perpendicularly

to the surface of the latter. (Fig. 222.) Neither the articular cartilages nor the fibro-cartilages of circumference contain either nerves or vessels, though the vessels of the synovial membranes sometimes intrude upon them at their borders.

Dr. Leidy, of Philadelphia, has also observed numerous minute lacunæ in articular cartilages. These are lenticular in outline, $\frac{1}{1200}$ to $\frac{1}{3120}$ of an inch in length, and most abundant in the deepest layer of the cartilage, and decrease in number towards its free surface. Another peculiarity, also described by Dr. Leidy, is the penetration of the structure of the articular cartilage by fibres or columns of bone. These fibres are compressed and cylindrical in shape, and present an elliptical outline on a transverse section. They are not numerous, are concentrically laminated, and present a radiated appearance, not very unlike an Haversian rod; but neither the Haversian canal, nor the lacunæ and pores, are to be seen.

Fig. 222.



Articular cartilage of a human metacarpal bone, cut perpendicularly. *a.* Most superficial, flattened cartilage-cells. *b.* Middle round cells. *c.* Innermost cells, disposed perpendicularly in small rows. *d.* Outermost layer of the bone, with ossified fibrous matrix, and thick-walled cartilage-cells, in this instance appearing dark from their containing air. *e.* True bone-substance. *f.* End of the cancelli of the epiphyses. *g.* One of the cancelli. —Magnified 90 diameters. (*Kölliker.*)

The condition of the bone beneath the articular cartilages is peculiar, consisting, in almost all joints, of a layer of incompletely formed osseous tissue. This layer is $\frac{1}{300}$ to $\frac{1}{75}$ (average $\frac{1}{100}$) of an inch thick, and is a yellowish, mostly fibrous, hard, and truly ossified matrix; containing, however, not a trace of Haversian canals or medullary cavities, nor any perfectly formed lacunæ. Instead, however, of these, are found roundish or elongated corpuscles, aggregated into little masses or rows $\frac{1}{2000}$ to $\frac{1}{500}$ of an inch long, and $\frac{1}{1500}$ to $\frac{1}{3000}$ of an inch broad. These give thin sections of the bone a perfectly opaque aspect; and are really thick-walled cartilage-cells, retaining their contents (fat and nuclei), occasionally

presenting indications of pores, and being perhaps also partly calcified. In other cases they are, in fact, undeveloped lacunæ. This layer is bounded towards the cartilage by a straight line, and towards the bone by a sinuous contour. It occurs in every articulation, except that of the lower jaw, and those on the os hyoides. (*Kölliker.*) (Fig. 222.)

In *pathological* states, the articular cartilages sometimes assume a fibrous structure, a change often attended by an increase of thickness. These fibres are sometimes half an inch in length. (*Cruveilhier.*) Sometimes they wear away rapidly, or even entirely disappear, leaving the bones bare. They may also be attacked by ulceration; this penetrating to the bone, or commencing next to it and extending towards the free surface.

The Synovial Membranes.

The synovial membranes are not closed cavities, as generally described; but merely of the form of rings, or short tubes, whose two open ends or borders are attached to the circumference of the articular surfaces of the bones, and thus connect them together. They are delicate transparent membranes, but are often invested externally by the capsular or other ligaments of joints, from which they are with difficulty separated.

Fig. 223.

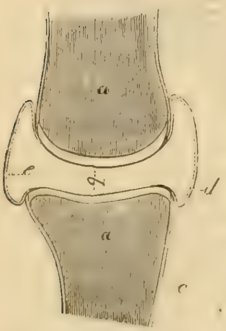


Diagram of a longitudinal section of a phalangeal articulation; partly after Arnold. *a.* Bones. *b.* Articular cartilage. *c.* Periosteum continuous with the perichondrium of the latter. *d.* Synovial membrane at the edge of the cartilage, connected at first with the perichondrium. *e.* Its epithelium. (*Kölliker.*)

The precise relations of the synovial membranes are as follows: They are attached simply to the border of the articular surface, and either thrown across directly to the other bone, or they may in the first place invest a small surface of the first bone also, as well as the cartilage, and then pass to the other bone. (Fig. 223.) In either case, the synovial membrane does not adhere directly to the hard tissues underneath it; but is more or less closely connected with the periosteum or the perichondrium. It finally terminates, without any distinct margin, near the border of the articular cartilage, being inseparably united with its perichondrium.

In their *intimate* structure, the synovial membranes consist—*first*, of a layer of condensed areolar tissue, with vessels and nerves; and, *secondly*, an epithelium.

1. The *corium* (or layer of areolar tissue) sometimes, though rarely, contains fat-cells in its meshes, and a few scattered cartilage-cells with thick, opaque walls.

2. The *epithelium* is composed of from one to four layers of large tessellated cells, $\frac{1}{2400}$ to $\frac{1}{1500}$ of an inch in diameter, with roundish nuclei of $\frac{1}{6000}$ to $\frac{1}{4000}$ of an inch.

The synovial membranes present large adipose masses and vascular processes. The former, once erroneously termed Haversian glands, are found principally in the hip- and knee-joints, and consist of collections of fat-cells in vascular portions of the synovial membrane. The *vascular processes* constitute red, flattened projections of the synovial membrane, with an indented and polished margin, furnished with minute processes. The folds are usually placed close to the junction of the synovial membrane with the articular cartilage, and lie flat upon the latter, forming a sort of coronal around it. They differ from the rest of the membrane in structure, principally in their great vascularity, since they consist of little else than minute arteries and veins, and delicate capillaries forming wavy loops at the edge of the processes; and hence resemble the choroid plexus in the ventricles of the brain. Besides the vessels, these processes consist of areolar tissue and the epithelium found elsewhere on these membranes. At the edge of these processes, projections of the membrane, of extraordinary forms (sometimes resembling the stems of a cactus), are found. It is these non-vascular processes which, being enlarged and then detached, constitute one of the forms of the erroneously so-called *loose cartilages* in joints, as has already been shown (p. 319, 2).

The nerves of the synovial membrane are but few in number.

The *synovia* is evidently secreted by the epithelial cells upon the vascular processes; and to a very slight extent also, doubtless, by those on the rest of the membrane. The properties of this fluid have already been stated (pp. 180 and 198). Its function is to diminish friction in the varied movements of the joints.

Inter-Articular Fibro-Cartilages.

The inter-articular fibro-cartilages may be mentioned here, though they do not actually come into contact with the bones. They are interposed between the two articular-cartilages of some joints (articulations of lower jaw, sternum and clavicle, &c.); or form mere projections between them (semilunar cartilages, so called, of the

knee-joint). In intimate structure they do not differ from other fibro-cartilages; except that the cartilage-cells are smaller and more abundant in the deep, and less so in the superficial portions (p. 314). In old persons, they lose their distinct fibrous structure, and assume a yellow or brownish color.

The inter-articular ligaments, so called, must also be classified with the preceding fibro-cartilages. They are not covered by synovial membrane; nor even by an epithelium, except for a small extent at their attached borders (*e. g.* ligamentum teres, &c.).

Connection of Tendons and Ligaments with the Bones.

Tendons and ligaments are generally inserted into the periosteum. Both are, however, in some instances inserted into the bone itself; there being no trace of periosteum intervening. This is the case with the tendons of the quadriceps femoris, pectoralis major, deltoid, latissimus dorsi, psoas-iliac, glutæi, the tendo-Achillis, &c., and the ligaments, mentioned on page 342, 2. In these cases the fasciculi of the tendon rest at an acute or a right angle on the surface of the bone, and become attached to all the elevations and depressions of its surface. Close to the bones, the tendons frequently also contain delicate cartilage-cells. They also, in exceptional cases, become entirely incrusted with calcareous salts in the form of granules, next the bone. Fig. 224 shows the peculiarities just mentioned.

The general structure of the proper *joints* or movable articulations (diarthroses) may be gathered from what has preceded. Each diarthrodial articulation contains the following elements:—

1. The articular cartilages, covering the extremities of the bones, described on page 343.

2. The synovial membrane, secreting the synovial fluid (p. 344).

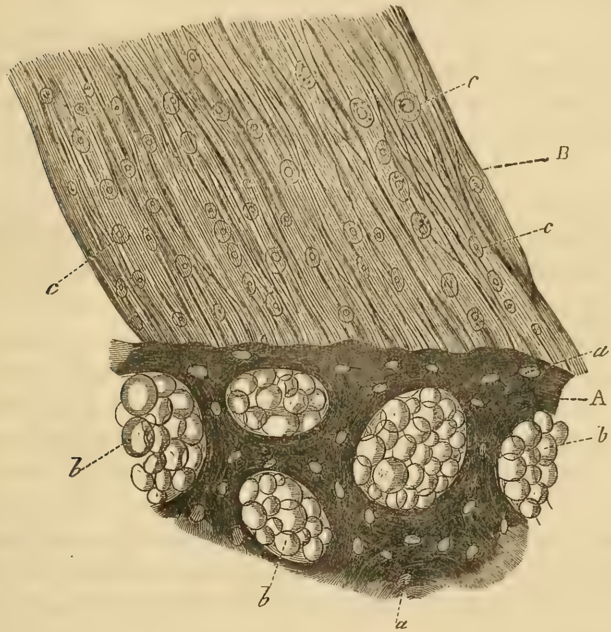
3. In some instances, inter-articular fibro-cartilages (p. 345).

4. Ligaments of various forms; inter-articular and circumferential (pp. 346 and 342).

The *amphiarthroses*, or symphyses, have a simpler structure. Here the connection of the bones is by cartilage alone, or associated with fibro-cartilage and white fibrous tissue. In the symphysis pubis, sacro-iliac synchondrosis, and the articulations of the bodies of the vertebræ, the surfaces of the bones are directly covered by a layer of true cartilage; and which in the first two situations, is directly connected with the opposite layer, and in the last, by means of fibro-cartilage and white fibrous tissue in consecutive layers. In the

first two cases also, there is frequently a cavity in the interior of the connecting substance; so that the sacro-iliac symphysis in par-

Fig. 224.



Insertion of the tendo-Achillis into the calcaneum of a man sixty years old. *A*. Bone with lacunæ, *a*; cancelli and fat-cells, *b*. *B*. Tendon; with tendinous fibres and cartilage-cells, *c*.—Magnified 300 diameters. (*Kolliker.*)

ticular may be regarded as a sort of movable articulation. (*Zaglas.*) Some of the articulations of this class are also surrounded by ligaments, described in all anatomical works.

In the *synarthroses*, the bones are united merely by an extremely thin membranous whitish streak, incorrectly termed the sutural *cartilage*. It is really white fibrous tissue, and it gradually disappears in old age, and is at last in many parts entirely removed, especially on the inner part of the sutures; and even before the complete obliteration of the latter. It is properly termed the *sutural ligament*, therefore.

Properties of the Bones.

The properties of the bones are those of the osseous tissue, already specified (p. 335), the most important being their rigidity

and density, and others incidental to these. Upon these properties their uses depend.

The *cohesive force* of bone is truly astonishing; it being twice as great as that of oak, though its specific gravity is to that of oak as 92 : 65.[1]

The *vertical strength* of bone, or its power as a column of support, and to resist pressure, is still more wonderful. Prof. Robinson found that a disk of bone one inch square, supported a weight of 5000[2] lbs. He does not, however, specify the thickness of the disk.

The power of the bones to resist flexion and fracture, or as mere *levers*, must also be mentioned here. Prof. Robinson found bone related, in this respect, to freestone, lead, and several of the strongest kinds of wood, as follows:—

Fine freestone	1.
Lead	6.5
Elm and ash	8.5
Box, yew, and oak	11.
Bone	22.

In other terms, bone is 22 times as strong in this respect as fine freestone; about 3½ times as strong as lead; nearly 2¾ times as strong as elm and ash, and twice as strong as box, yew, and oak.

Uses of the Bones.

The bones in their aggregate constitute the *osseous skeleton* of the vertebrate animals.[3]

1. The skeleton gives firmness to the body and preserves its symmetry. The spinal column and the cranium at the same time also protect the spinal cord and the encephalon; and the bony walls of the thorax and pelvis, the contents of these cavities respectively. All the bones, moreover, afford fixed points for the attachment of the muscles.

2. The long bones are acted upon by the muscles as levers, and hence are the passive organs of the motions; those of the lower extremities being subservient to locomotion, and those of the upper,

[1] London Lancet, April, 1846, p. 346. [2] Ibid., p. 240.

[3] At the age of 21 years, the weight of the skeleton is to that of the whole body (the latter being 125 to 130 lbs.)—as 10.5 : 100 in man, and as 8.5 : 100 in woman.

to the infinity of movements of which the latter are capable. The ribs are thus subservient to the movements of respiration.

3. The long bones especially manifest the power to resist fracture before illustrated, and to this effect the hollow cylindrical form of their diaphyses greatly contributes. Indeed, if the weight of the shaft, and the length, be the same, its strength as a lever varies (within certain limits) *directly as its diameter*, *i. e.* if the shaft of the os femoris, weighing sixteen ounces, and being seventeen inches long, is hollow and one inch in diameter, it is twice as strong as if of the same length and weight, and condensed into a solid rod half an inch in diameter. Thus we perceive the advantage resulting from the function of the medullary canal in the long bones; viz., to increase the strength of the bone, the amount of material in it being given. Every blade of grass, indeed, is constructed on the same principle. This arrangement is also apparently more consonant with the power of rapid repair after fracture in the long bones; in which fractures must necessarily be most frequent. Finally, the existence of the cavity necessitates the presence of a substance to fill it, which is accomplished by the marrow, as above explained (p. 341).

4. But the long bones are also for support, especially in the lower extremities; and in this relation some interesting facts are ascertained. The strength of bone as a mere column of support, its weight and general conformation being the same, varies *inversely with the square of its length; i. e.* an os femoris $8\frac{1}{2}$ inches long, and weighing 17 ounces, would be four times as strong as one twice as long, but of the same weight. Hence the short bones are vastly stronger in proportion, in this respect. Indeed, we may imagine the lower extremities of an animal to become incapable of sustaining its weight, from a slight increase of their length, while the bones become no heavier. Hence only animals having light bodies have long extremities; while the very heavy have proportionally short columns of support. Hence, also, the tarsus and carpus of the lower animals, as well as man, consist of short bones. Moreover, the speed of animals cannot be increased in proportion to size; the skeleton becoming at length so heavy that much muscular force is exhausted in merely sustaining it.

5. Man has comparatively a long column of support, especially so far as the os femoris is concerned; and thus the power of rapid locomotion is secured. The diminution of strength consequent on

its length is, however, in part compensated by the fact that the peculiar attachment of the cervix femoris converts this bone (as a column of support) into an arch; and thus brings its elasticity also to bear on its strength.

Development of the Bones.

Most of the bones are developed in cartilages, which, in the aggregate, constitute the cartilaginous skeleton (p. 316); the rest being formed in a soft blastema. The former are sometimes termed *primary*, and the latter *secondary*, bones.

The cartilages constituting the cartilaginous skeleton are developed like other true cartilages (p. 317), and grow in a similar manner, till ossification commences within them; and which extends from within outwards till the whole is converted into—or, more accurately speaking, is replaced by—bone.

The cartilaginous skeleton, and its conversion into the various bones, will first be described; and then the development of the secondary bones (the flat bones of the cranium, &c.) will be explained.

It follows that the *primary cartilaginous skeleton* is not so complete as the osseous skeleton; but it also presents some portions which either remain in a cartilaginous state, or are subsequently entirely removed. It consists—*first*, of a complete vertebral column, with as many cartilages as there are afterwards osseous vertebræ, and with intervertebral ligaments; *secondly*, cartilaginous ribs and sternum; *thirdly*, cartilaginous extremities with as many pieces as there are subsequently bones, except that the pelvic cartilages are in a single mass; and, *fourthly*, an incomplete cartilaginous cranium. The last forms a continuous cartilaginous mass at first, and corresponds to the occipital bone (except its upper half), the sphenoid (except the external lamina of the pterygoid process), the mastoid and petrous portions of the temporal bone, the ethmoid, the inferior turbinated bone, the hyoid bone, and the *ossicula auditûs*. The cartilaginous cranium also presents the parts before alluded to, as either remaining in a cartilaginous state, or entirely disappearing—as Meckel's process, two cartilaginous lamellæ below the nasal bones, a narrow band connecting the styloid process with the hyoid bone; another extending from the outer part of the *ala parva* to the *lamina cribrosa;* and a third reaching upwards and forwards from the cartilaginous mastoid and petrous portions of the temporal bone.

Thus in the cartilaginous cranium the vault is entirely wanting, and almost all the lateral portions, as well as nearly all of what afterwards becomes the facial bones. The parts not formed of cartilage are, however, closed by a fibrous membrane, so that the cranium is nevertheless at this time complete. It is also in this membrane that the *secondary* bones are subsequently developed.

The *changes* which occur in the primordial cartilaginous skeleton are, therefore, of three kinds: 1. Some portions subsequently *disappear* altogether, as already stated. 2. Other portions undergo subsequent development with the rest of the skeleton, constituting the *permanent* cartilages of the nose, joints, symphyses, and synchondroses. 3. The third and greater part finally becomes ossified, forming all the bones of the trunk and extremities, and a great part of those of the cranium. It is this portion—the *ossifying cartilages*—whose changes are to be described here.

The general description of the ossification of the cartilages is as follows: At one or more points in their interior, calcareous matter begins to be deposited, simultaneously with a change in the elements of the cartilage. The latter, in most cases, ceases to grow in one direction while this change is going on, and is therefore soon entirely converted into bone; while in other directions its growth continues, so that a new cartilaginous material is offered for the progressive increase of the bone. When the bone has attained to its ultimate length, the cartilage becomes completely ossified, and ceases to be developed, its perichondrium now being a periosteum. The diameter of the bone is, however, still increased by the formation of concentric laminæ (the fundamental laminæ, p. 328) underneath the periosteum, from the blood-plasma in the periosteal vessels.

The *minute* changes in the ossifying cartilage are next to be described, and Kölliker's view of this difficult subject will be adopted as the most satisfactory.

It should, however, be premised that the *cancellated* tissue *alone* is developed from the primordial *cartilages*, the compact tissue being derived from another source. When, therefore, the cartilages have become ossified, the bones thus formed all consist entirely of cancellated tissue. The following description, therefore, of the ossification of the cartilages is the history of the *development* of the *cancellated bone-substance*, wherever found:—

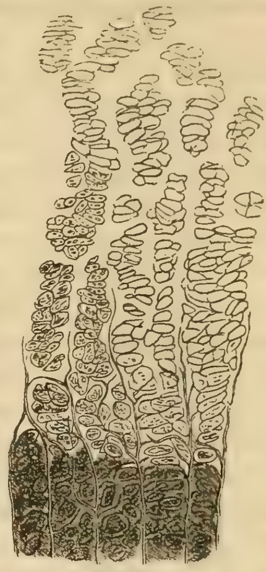
I. Before ossification actually commences, vessels begin to penetrate the ossifying cartilages. They appear from and after the

middle of fœtal life, preceding by a longer or shorter time the appearance of the centres of ossification, and accompanying the latter as they increase. They may still be seen in the epiphyses of the long bones in a person even eighteen years old. They always lie in wide canals ($\frac{1}{600}$ to $\frac{1}{300}$ of an inch even in a fœtus of five months) excavated in the cartilage, and bounded by narrow, elongated cartilage-cells. They enter the cartilage from the perichondrium at first, and, after an osseous centre exists, from the border of the latter also; proceeding in straight lines in various directions, and giving off a few branches, which seem not to anastomose at all, but to terminate in blind, club-shaped dilatations. These canals are produced by an absorption of the elements of the original cartilage-substance, and they originally contain a plastic material (cartilage-marrow) composed of minute rounded cells, from which true blood-vessels are developed. Of the vessels themselves, sometimes but one large one; frequently two, distinctly arterial, with muscular walls; again, only capillaries in various numbers—are found in a single canal. It is not precisely understood how the circulation is carried on by them. Their object is, doubtless, to afford a greater amount of nutritive material, both for the changes in the cartilage preparatory to ossification, and for the development of the bone itself. That they are merely an accidental production, as H. Meyer maintains, is highly improbable.

II. Together with the formation of vessels in the cartilages, the elements of the latter undergo important changes. The cartilage-cavities, before of small size, and containing but few cells, begin to grow, and successive generations of cells to be produced in them in the following manner: Each cell is first divided into two by segmentation transverse to the line of ossific advance; these are again subdivided, and the process repeated till long lines of cartilage-cells extend in the elongated cartilage-cavities from the border where ossification has taken place.[1] The size of the cavities, however, does not increase after birth. When the ossification of the cartilage proceeds in one direction only, they are grouped in rows at the border of the cartilage, in which the long cavities are being developed. This is best seen in the extremities of the shafts of the larger long bones; the rows of cavities being arranged in parallel lines, close together, and of considerable length, as shown by Fig. 225.

[1] Tomes and De Morgan.

Fig. 225.



Vertical section of cartilage at seat of ossification. The clusters of cells are arranged in columns, the intercellular spaces between them being 1-3250th of an inch in breadth. At the lower end of the figure osseous fibres are seen occupying the intercellular spaces, at first bounding the clusters laterally, then splitting them longitudinally, and encircling each separate cell. The greater opacity of this portion is due to a threefold cause: the increase of osseous fibres, the opacity of the contents of the cells, and the multiplication of oil-globules.

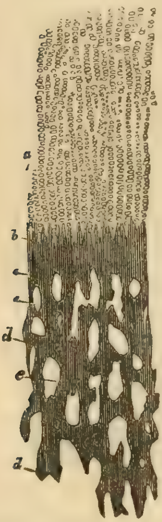
Where, however, the ossification extends in all directions from a centre, the cartilage-cavities are confusedly grouped in roundish or oval, irregular little masses, as in the short bones, and the epiphyses of the long bones. In both these cases, however, the cavities containing the cells (the latter being in a single or double linear series, or in a more globular mass), are the elongated original cartilage-cavities. The thickness of the layer around and beyond the bone, which presents the arrangement of cells just described, varies in the different cartilages; being $\frac{1}{48}$ to $\frac{1}{24}$ of an inch in the shafts of the long bones, and very thin around the osseous centres, in the epiphyses, and in the short bones. It is always yellowish, streaky, transparent, and apparently fibrous; while the surrounding cartilage is, as usual, bluish-white, with a hyaline or granular intercellular substance.

III. The preparations for ossification being completed by the development of the vessels and the arrangement of the cartilage-cells just described, the osseous tissue now begins to appear. And as true cancellated bone-substance consists originally of only the lacunæ and pores and the surrounding true osseous tissue, and the cancelli (with their marrow and its vessels), we have to inquire how these are developed respectively.

1. The *true osseous tissue* is usually developed before the lacunæ and pores are formed; and its formation occurs mainly in the intercellular substance of the cartilage, its cells still remaining unchanged. The first apparent change in this is the deposit of very fine granules of the earthy constituents of bones, varying in size from an immeasurable minuteness up to $\frac{1}{12000}$ to $\frac{1}{6000}$ of an inch in diameter. When the cells are disposed in rows at the ossifying border, this disposition of earthy matter always forms columns between the

rows of cartilage-cells, forming pointed tooth-like processes between the individual cells, and surrounding the lower portion of the rows like short tubes. (Fig. 226.) If, however, this granular deposit be traced back from the ossifying margin into the substance of the new bone, it gradually becomes clearer, more homogeneous and transparent, and ultimately acquires the aspect of perfect bone; the earthy granules apparently becoming gradually fused together, and thus disappearing as isolated distinguishable particles. And thus the true osseous tissue is developed (though not entirely, as will appear), in the matrix or *intercellular* substance of the ossifying cartilage. (Fig. 225.)

Fig. 226.



Vertical section through the cartilage and incipient bone of the diaphysis of the femur; in an infant a fortnight old. *a*. Cartilage-cells arranged in longitudinal piles near the ossified surface. *b*. Plane of ossification, the osseous matter inclosing the basis of the piles. *c*. Close osseous network first formed. *d*. Cancellated structure formed by the absorption of parts of this. *e*. Its cancelli filled with medulla.

2. But while the intercellular substance thus gives place to true bony tissue, the *cartilage-cells* also are being converted into the future lacunæ and pores of the bones. And it may now be regarded as established by Kölliker's investigations, that each cartilage-cell becomes converted into a single lacuna and its pores as follows, except where several are fused together into a compound lacuna: 1. The cartilage-cells become filled with concentric layers of osseous tissue, the external one being formed first, and the last or internal layers showing imperfections or indentations. This proceeds till the cartilage-cell is more or less completely filled with the osseous matter, though a cavity always remains (the future lacuna), containing generally the nucleus of the original cartilage-cell, and a fluid plasma. 2. Minute canals (the pores) are next formed by actual *absorption*[1] of the bone-substance; and thus are completely perforated by them, both the osseous tissue deposited within the cartilage-cells, and that previously found in the intercellular substance of the cartilage. 3. Finally, the osseous tissue within the cells becomes fused with that preformed between them, so that

[1] The cause of this absorption is not understood.

no distinct walls of the lacunæ can be recognized (p. 324); and thus the formation of the whole of the true osseous tissue is accounted for, together with the lacunæ and pores.

3. The *cancelli* are developed by absorption of more or less perfectly formed bone-substance. During the ossification of the shafts of the long bones, the osseous tissue, to the thickness of $\frac{1}{60}$ to $\frac{1}{36}$ of an inch, is compact, and without a trace of larger cavities; being composed partly of the ossified intercellular substance of the cartilage, and partly of the cells of the latter, more or less advanced in their transformation into lacunæ and pores. But beyond this depth, cavities at first small, and, more internally, larger, are seen, which appear to be eaten out of the bone, and involve both the osseous tissue, the lacunæ, and pores, and the still unossified portion of the cartilage. How this absorption takes place is also unknown.

Thus it appears that while the formation of bone progresses in one direction, an active resorption of a part of the bone thus formed follows. The cancelli thus formed are of different form, size, and direction, in different bones.

As the medullary cavities or cancelli become developed, they are also filled with a soft reddish substance—the fœtal medulla—consisting at first of merely a small quantity of fluid and many rounded cells containing one or two nuclei, and faintly granular contents. Subsequently, however, these cells become identical with those already described as occurring in certain bones in the adult (p. 340); and are developed in the usual way into areolar tissue, bloodvessels, fat-cells, and nerves—or the true marrow of the bones (p. 340). The vessels are formed very rapidly, and the fat, and then the nerves, afterwards; so that vessels appear in the cancelli very soon after the formation of the latter. The fat-cells are few even at birth, and the nerve filaments much fewer than subsequently; the medulla being now colored entirely red by the blood, and the light-reddish medulla-cells. These vessels extend into the cancelli from the cartilage vessels already described (p. 352).

Thus the bone-substance formed from cartilage alone, is merely *cancellated.* Hence the shafts as well as the epiphyses of the long bones, at first contain only cancellated or spongy tissue; the compact bone-substance being subsequently superadded from another source, as next to be described.

Development of the Compact Bone-Substance.

This is developed from *a layer of plasma, underneath and afforded by the vessels of the periosteum.* In the fœtus of five months, this layer is so firm as to be detached with the fully formed periosteum, forming upon the latter a moderately thick, soft, whitish-yellow lamella very much resembling immature collagenous (white fibrous) tissue, and containing granular, oval, or round nucleated cells, $\frac{1}{2000}$ to $\frac{1}{1200}$ of an inch in diameter. This lamella is very extensively connected with the superficial layer of the bone, and on being detached, a few little fragments of bone and scattered masses of reddish soft medulla from the most superficial cancelli, will be seen on the inner surface.

The cells just mentioned appear exactly like the fœtal medulla-cells, but not at all like those of cartilage. And it appears that the collagenous matrix is next ossified by the simple uniform deposit of the calcareous salts, though without the previous appearance of calcareous granules as before described (p. 354); while from the cells the lacunæ and pores are developed.

Bone formed in this way, however, does not constitute connected and parallel layers, but interrupted reticular lamellæ, and the spaces left between the latter $\frac{1}{750}$ to $\frac{1}{500}$ of an inch in diameter, are the rudiments of the Haversian canals of the compact bone-substance. These spaces at first contain only the unossified portion of the plasma just described. But vessels communicating with those of the interior of the bone (of the cancelli), and with those of the periosteum, soon appear in them; as well as the usual light-reddish medulla-cells, and certain peculiar cellular corpuscles, with from three to twelve or more vesicular nuclei and nucleoli, which are probably referable to the multiplication of the latter. The vessels just mentioned are the future Haversian vessels; and finally the Haversian rods consisting of the concentric (or spiral) lamellæ, with their lacunæ and pores, are developed around the vessels—the outer lamellæ first; and thus the development of the compact bone-substance is completed. The manner in which the interrupted laminæ are formed, and which are now seen to constitute the interstitial (or inter-Haversian) bone-substance (p. 330), is shown by Fig. 227. A vertical section of the sub-periosteal layer of developing osseous tissue is shown by Fig. 228.

The compact tissue continues to be formed, as just described,

until the bone attains to nearly its full development, when the general (fundamental) laminæ (p. 328) are formed externally to the Haversian rods from a plasma afforded by the vessels of the peri-

Fig. 227.

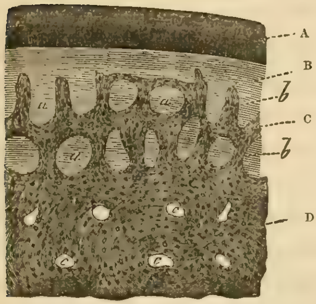


Fig. 228.

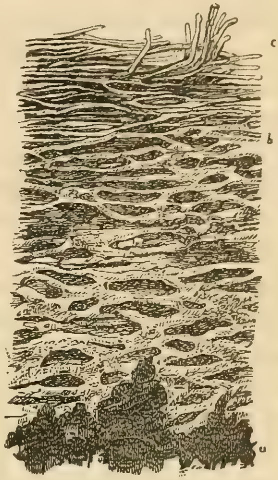


Fig. 227. Vertical section from the surface of the shaft of the metatarsus of the calf; magnified 45 diameters. A. Periosteum. B. Ossifying blastema. C. Young layer of bone with wide cavities (*a*) in which are lodged remains of the ossifying blastema, and reticular spiculæ (*b*), which towards the blastema present a tolerably abrupt border. D. More developed layer of bone, with Haversian canals (*c*) surrounded by their lamellæ. (*Kölliker.*)

Fig. 228. Sub-periosteal layer from the extremity of the shaft of the ossifying tibia. The cartilage and more open bony tissue have been scraped off from the inside of the crust, except at (*a*), where a dark shade indicates a few vertical osseous areolæ, out of focus and indistinctly seen. The part (*a*, *b*) of the crust is ossified; between (*b* and *c*) are the clear reticular fibres, into which the earthy deposit is advancing. (Magnified 150 diameters.)

osteum, to constitute the structure represented by Fig. 217. And by these the thickness of the bone is increased. But, while this change is going on in the outer portions of the shaft of the long bones, another is occurring in its interior; viz., the whole original shaft of cancellated bone-substance, formed from the cartilage, becomes by degrees absorbed, and thus the medullary canal is formed. The extremities, however, of the long bones being formed entirely from the original cartilages—the latter constantly growing and becoming ossified, while the bone is increasing in size—are not absorbed internally; but, like the short bones (which also are not formed from a collagenous matrix derived from the periosteal vessels), continue to retain the cancellated structure through life. It is, however, sufficiently obvious that the medullary canal is formed, not at the expense merely of the cancellated substance in the shaft of the fœtal

bones; but that it also implies an absorption of a considerable portion of the compact tissue at first formed. In fact, while, during the growth of the bones new osseous tissue is constantly deposited externally, that also which is already formed is as constantly absorbed in its interior. So that during its growth each bone is several times regenerated; and the humerus, for instance, of the adult, does not contain an atom of the osseous tissue existing in it at birth.

The fact, however, that a thin layer of compact bone-substance is formed by the periosteum on the exterior of the short bones also, has been stated. Absorption and regeneration of the cancellated structure occurs also in the short as well as in the long bones; but far more slowly. Hence in them (*e. g.* the vertebræ) we find more or less still remaining, of the earlier bone-structure. It should also be added that some of the Haversian vessels being enlarged, constitute the *vasa nutritia* of the interior of the long bones. And finally, when the long bones attain to their full length, the osseous tissue of the diaphysis and of the epiphyses becomes completely fused together, the disk of cartilage which hitherto intervened, now disappearing entirely; and the vessels originally distributed separately to the shaft and the extremities, at last forming anastomoses, though not very numerous, through the last formed portion of the bones. If the question occurs how bone is developed externally at points covered directly by tendons and ligaments, without the intervention of periosteum (p. 346), it may be suggested that these also must and do increase in size, and are also constituted of the collagenous tissue, like the blastema afforded by the periosteum. At any rate, interstitial changes must be occurring in the ligaments and tendons till they attain to their full development; simultaneously with which, similar changes must occur in the surface and the size of the bones to which they are attached. It is only by admitting interstitial changes in bone, moreover, that we can account for the increase in size of their foramina, and in the length of the laminæ of the vertebræ, &c.

Development of the Secondary Bones.

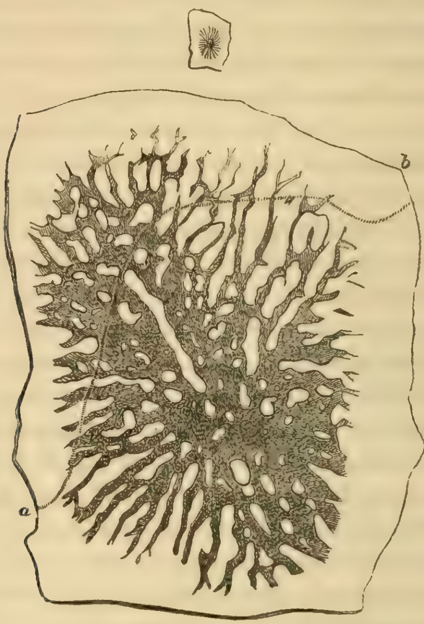
Bones not previously cartilaginous occur in man, only in the roof of the cranium and the face. They are called *secondary*, because their development does not commence till after that of the primordial or cartilaginous cranium (p. 350). This class includes

the upper half of the expanded portion of the occipital bone, the parietal and frontal bones, the squamous portion and tympanic ring of the temporal, all the bones of the face, except the inferior turbinated bones; and apparently the internal lamella of the pterygoid process of the sphenoid bone. It will, however, appear that these bones are developed in precisely the same manner as the periosteal layers, or compact tissue of the other bones.

The secondary bones of the cranium all commence in a membraniform blastema lying between the dura mater and the integuments, whose growth advances with the development of the osseous tissue within it. The latter commencing in a single point, radiates in all directions and thus forms a delicate lamina of reticulated osseous spiculæ, giving off slender rays into the still unossified blastema. Minute examination shows that the spiculæ are formed by the ossification of the elements of the blastema, though to a certain extent the latter is absorbed to give place to them, while it still fills the interstices between them; and that the formation of the bone-tissue proceeds exactly in the same way as in the periosteal layer of the primary bones. (*Kölliker.*) At first, the growth proceeds in a superficial plane only, the rays forming a network as they come into contact with each other, as shown in Fig. 229. Additional layers are, however, soon added to both surfaces of the original one, and thus the structure becomes thicker, and at the same time also more compact. The thickening layers are, however, referable to the periosteum which is found on the secondary bones soon after their development has begun; so that in fact only the primary layer presents any apparent peculiarity in development. The bone increases in extent by the formation of new blastema in contact with that just about to be ossified, until it has attained to its full size; and it is constantly increasing in thickness by the addition of the periosteal layers as just explained. Interstitial changes are also at the same time going on, and the final result is, the formation of the bones with their compact layers and Haversian canals; and their cancelli internally, constituting, in case of the cranial bones, the diploë. The cells in the blastema never resemble cartilage-cells, except those at the edges of the newly formed bone. But Kölliker doubts if even these be true cartilage-cells. It has already been seen that it is not true cartilage which connects the cranial bones together in the adult, but collagenous tissue instead (p. 347). There is usually but one centre of ossification for each of the se-

condary cranial bones; or for each half, when one is symmetrical. The spaces left between them at birth, from the fact that their angles

Fig. 229.



Process of ossification in parietal bone of an embryo-sheep of two and a half inches in length. The small upper figure represents the bone of the natural size. The larger figure is magnified about 12 diameters. The curved line (a, b) marks the height to which the subjacent cartilaginous lamella extended. A few insulated particles of bone are seen near the circumference, an appearance which is quite common at this stage.

are still undeveloped, are termed the *fontanelles;* and this condition allows an overlapping of the bones of the vault of the cranium, by which parturition is very much facilitated.

The secondary bones are more vascular while growing than afterwards; more so even than the periosteal layer of the other bones; many of the vascular canals afterwards becoming much contracted, or even obliterated.

For the facts in regard to the precise period when each bone is developed in the fœtus, the works on anatomy are referred to; the law being that *the bones, and even the parts of bones, first needed in the skeleton are first developed.*

Remarks.—1. In regard to the amount of osseous tissue developed in a given time in a young animal, the following facts may be

noted. Boussingault determined from his experiments that the skeleton of a pig increases daily during the first eight months after birth, about 2.9 drachms in weight (average); amounting to a formation of about 1.55 drachm daily of osteine, and 1.35 drachm of earthy matter, including .6 drachm of phosphoric acid. Subsequently to the eleventh month, the daily increase in weight averages but 1.5 drachm daily; there being only about .65 drachm of earthy matter, including .35 drachm of phosphoric acid.

2. Much discussion has arisen on the question whether bone is always developed from cartilage—those who maintain the affirmative asserting that the blastema in which the periosteal layers of the primary bones, and the whole of the secondary bones are developed, is also cartilage, but in its rudimentary stage of development. It has already been seen that the cartilage-cells cannot at first be distinguished from the primordial cells of other tissues. So far as this fact is considered, therefore, it is as valid a proof of the assumption that the blastema is a rudimentary collagenous, as that it is a rudimentary cartilaginous tissue. The fact, however, that the intersutural substance contains no chondrine and never becomes cartilage, though remaining till late in life, and finally ossifies, especially internally, without going through that change; it being, on the other hand, white-fibrous tissue (the sutural ligament, p. 347)—militates against the idea that the secondary bones are developed from cartilage. Moreover, Kölliker appears to be correct in the assertion that the periosteal layers of the primary bones are developed in precisely the same manner. We, therefore, believe with him—against Meyer and many other histologists—that while the cancellated substance of the primary bones is developed in cartilage, the secondary bones, as well as the periosteal layers of the primary, are developed in a matrix homologous with white fibrous tissue.

Indeed, if we trace the development of the skeleton through the animal series, we find, 1, that in all vertebrated animals those parts of it requiring some degree of firmness during the early periods of development, consist of cartilage; while the rest is developed from a softer substance. The cartilaginous portion will constitute more or less of the whole future skeleton, according to the habits, &c., of the animal; *e. g.* the cranium of the pig is more exclusively cartilaginous than the human cranium. 2. In some of the lowest vertebrata (cartilaginous fishes), the skeleton remains in the cartilaginous state through life. 3. In all the land vertebrata, however, a

firmer skeleton is required, and the greater part of the cartilaginous skeleton therefore becomes replaced by bone; while equally firm bones are at the same time developed from the softer blastema before described. Thus there appears to be no necessity for cartilage as a matrix for the development of bone, unless required on account of its greater firmness; and Meyer's assumption that everything in which bone is formed is *cartilage*, is both a begging of the question, and, at the same time, incorrect.

3. The *manner* of development of bone is, however, essentially the same, whether cartilage or a soft blastema be the matrix. In both cases it is developed as an entirely *new* tissue, and the pre-existing tissue disappears and gives place to it. It has been seen that the true *osseous tissue* is first developed in the intercellular substance of the cartilages, and finally the whole of it *appears* to be converted into bone. There are, however, no facts indicating that chondrine can be converted into glutin, or cartilageine into osteine (p. 100). This element of the cartilage is therefore merely *replaced by* the osseous tissue. On the other hand, it has been seen that the cartilage-*cavities* remain for a time, increasing in size and changing their forms; but the cartilage-*cells* within them, after increasing in number, disappear (except probably their nuclei), the lacunæ (and pores) taking their place in part (p. 354, 2).

Again, while the secondary bones are forming in the membranous expansion of collagenous tissue, the latter disappears, being replaced by them (p. 359). It is apparently only the soft and still unorganized blastema in contact with the collagenous tissue that can be converted directly into osseous tissue. And the probable reason why the latter is transparent when first formed in the case of the periosteal layers, is, that perfect osseous tissue is at once formed; while, when formed in cartilage, the earthy matter only is first deposited, and the osteine is subsequently formed and combined with it.

In both cases, therefore, the cartilage and the collagenous tissue respectively are merely the *matrix* in which the bone is formed, and which disappears progressively with the formation of the latter. Nor can the idea that the same modified plasma may be developed into the collagenous tissue on the one hand, and the osseous on the other, be deemed singular. Both contain the same organic immediate principle (osteine); and the latter differs from the former more especially in containing a greater amount of mineral constituents.

Growth of Bone.

The long bones increase in length principally at the expense of the cartilage intervening between the shaft and the epiphyses; this constantly growing in the longitudinal direction, and giving place to bone. But the growth of the short bones, and of the long ones in thickness, has been regarded as a difficult subject to comprehend. The difficulty has, however, arisen from the erroneous assumption that the osseous tissue, once developed, undergoes very slight, if any, interstitial changes. Tomes and De Morgan have shown (p. 325) that very active processes of disassimilation and regeneration occur in the bone-substance. But, once admitting this fact, there is no more difficulty in understanding how a bone than how a muscle or any other organ increases in size, whether in all or only in particular directions.

Much stress has been put upon experiments with madder upon young animals, in connection with this question.[1] This coloring matter has a strong affinity for the phosphate of lime in the bones, and hence, when given in the food, imparts to them a pink color; and it was assumed that it combines with only the osseous tissue which is formed while the madder is being taken by the animal. It has, however, been proved by Brullé and Huguèny that it colors all the osseous tissue, even in adult animals, within a certain distance of the bloodvessels; and that the color remains in adult bones, though it is again removed in growing animals. Very little importance, therefore, can be attached to these experiments, except so far as that, when rightly interpreted, they also show (contrary to what had been meanwhile assumed), that a very active metamorphosis is constantly going on in the osseous tissue, at least till the osseous system has attained to its full development.

Reparation of Bone.

Osseous tissue is more perfectly regenerated than any other tissue whatever. This fact may be associated with another—viz., that no other tissue can, in case of the long bones especially, at all supply the place of the true osseous tissue; so that nothing less than a complete regeneration of the original tissue is compatible with the continued function of the injured bone.

[1] In very young animals a single day serves to color the entire substance of the bones.

This proposition is illustrated in caries, where there is merely a loss of bone-substance, and in solutions of continuity, or fractures; the repair in both cases taking place by the formation of true osseous tissue. In the former case, the new bone is formed from a blastema poured out by the periosteum of the bone; but repair after fracture demands a more particular description.

In most cases of fracture of the long bones of the lower animals, and in those occurring in man which are, for any reason, with difficulty kept in apposition during treatment, the formation of the new osseous tissue is preceded by that of cartilage; and in which the osseous tissue is subsequently developed, as are the primary bones at first (pp. 351—8). This cartilage has been incorrectly termed the *provisional callus*, and has been said by many writers to be always necessary for repair after fracture. Mr. Paget has, however, shown that this is not the fact; and that where the fractured extremities of the bones are kept in accurate apposition, and at rest, it is not formed at all in man; but the new bone is developed directly from a blastema, in the exudation of which the periosteum doubtless performs the most important part. Indeed, all unbiased observers must have been unable to perceive any trace of provisional callus during recovery from the most favorable cases of fracture of the radius and of the tibia, where it may be felt whenever it actually exists.

In fracture of the shaft of the long bones, the newly-formed bone at first entirely closes up the medullary canal; thus forming a plug entering and connecting the fractured extremities.[1] But when this becomes more consolidated and sufficiently strong, the central portions are reabsorbed, and the medullary canal again extends through the shaft of the bone as before. It usually requires two years or more to accomplish this object; after which the new bone-tissue at the point of fracture is as perfect as that of any other part of the bone, though some sign of the injury probably always remains.

In some cases, however, fractures do not unite by the reproduction of bone; but the fractured extremities are united merely by cartilaginous tissue (or ligament), and then a sort of articulation is found at the point of fracture. This is the case almost invariably in fractures of the neck of the thigh-bone within the capsular liga-

[1] It is this which Dupuytren, who first used the term, designated as the *provisional callus.*

ment, fracture of the olecranon process, and that of the patėlla. It is also common in fracture of the spongy bones, and may occur in fracture of any bone under unfavorable circumstances; of which a want of rest at the point of fracture is the most common, though by no means the only one. In some cases a want of plasma or of plasticity in it, is the cause of non-union by bone.

The question whether the plasma from which the new osseous tissue is developed is exuded by the periosteum alone, or by the other soft parts also, is not so important as some authors seem to have held. Obviously it can make no difference whether it be poured out by the vessels of the periosteum alone (as it certainly is in part), or not. Whencesoever derived, however, it can be organized into bone only while in contact with either bone or periosteum; and hence the importance of leaving all the spiculæ of bone in place, in cases of comminuted fracture, as centres of ossification for repairing the injury—provided they are not so detached as to cause irritation as foreign bodies.

Finally, cases occur in which entire bones have been reproduced after removal, provided the periosteum had been preserved. This has occurred with the lower jaw-bone, the ribs, the scapulæ, and the clavicle in a case known to the author. A rudiment of bone has sometimes been reproduced in the lower animals, when the whole periosteum, as well as the bone, had been excised. (*Heine.*)

Pathological Conditions and New Formations of Bone.

The changes in the chemical composition of bone in its various pathological states have already been noticed on pages 334—5.

I. *Hypertrophy* of bone assumes various forms, which may, however, be reduced to two classes: (1), external deposits (hyperostoses), formed chiefly from the periosteum; and (2), internal deposits, or sclerosis.

1. In regard to the hyperostoses (exostoses and osteophytes), Virchow shows that those of the cranium are formed directly from white fibrous tissue, without the intervention of cartilage. Sometimes the new bone-structure is perfectly normal; sometimes not so. They appear from periostitis, and in arthritis, syphilis, &c.

2. In sclerosis (osteosclerosis), the substance of the bone is more dense and harder than usual, and the term *eburnation* has been here applied. Here the Haversian rods are increased at the expense of the cancelli and the medullary canal. The lacunæ also appear to contain calcareous salts, and are more opaque than usual.

II. *Atrophy* of bone manifests itself in old age (senile atrophy of the bones), and a similar condition may occur in tuberculosis, sy-

philis, gout, rickets, &c.; or from the presence of aneurism, abscesses, sometimes from tumors, osteophytes, &c. The latter produce their effect by cutting off the supply of blood to the bone, from compression of its nutrient vessels.

If the circulation through the vessels of the medulla be interrupted, a brownish-yellow pigment is formed in the medullary canal, in the areolar tissue of the marrow. This is most common in old persons.

If the circulation through the *periosteum* be interrupted, it first becomes atrophied itself, as is indicated by its shrinking, or by the softening of its substance, together with the loss of its silvery lustre, and its diminished adhesion to the bone. Simultaneously, also, the bone becomes atrophied. In some cases of dropsy, the bone-substance becomes lighter, it having undergone a partial resorption (as in senile atrophy, syphilis, cancerous cachexia, paralysis, &c.); in others, it may disappear entirely (as in chronic diseases, paralysis, and anchylosis).

III. *Fatty Degeneration of the Bones* (Osteostearosis) may be regarded as one form of atrophy. It is most common in old persons affected with apoplexy or cancer, and is indicated by the presence of one or two, or even of entire groups of fat-globules in the lacunæ, and sometimes even in the pores. (Fig. 196.) In the latter case they are, however, isolated, wide apart, and far smaller. The bone has a yellowish color, and a greasy feel, and a diminished transparency when examined in thin plates. It has a greasy, liquefied medulla, and oil continues to exude in spite of repeated boiling. This also constitutes one form of mollities ossium, while rachitis is another.

IV. Death of bone (necrosis), occurs sometimes from ostitis, and always where the periosteum has been destroyed. There the lacunæ are but little changed; while the true osseous tissue is granular and of a dark color.

V. Peculiar conditions exist in osteoporosis, osteomalacia, and rachitis, and the chemical changes in the last disease have already been specified (p. 335). Osteoporosis consists in a dilatation of the cancelli, and of the Haversian canals. In *osteopsathyrosis*, the bone becomes extremely brittle from atrophy, with resorption of the lamellæ surrounding the Haversian canals.

VI. *Cancer and tubercle* occur in bone, the former, however (especially the medullary form), far the most frequently. The latter is believed by some to constitute the true pathological condition of the bone in morbus coxarius. Here we find invading the bone substance, the cancer-cells, and the tubercle-nuclei (pp. 139 and 117).

VII. Pathological *new-formations* of bone (true ossification), occur in a variety of parts and organs, especially in the periosteum and dura mater, and in tendons and ligaments. Indeed, the possibility must be admitted that true bone, distinguished by lacunæ and pores, may be developed in any part or organ consisting previously of

cartilage, or of the white fibrous tissue. The ossification, so called, of arteries, and the valves of the heart is not actually so, since no true osseous tissue is formed. It is mere *calcification*, and consists merely in a deposit of calcareous salts (mainly the carbonate and phosphate of lime) among the histological elements of the part affected. True *ossification* occurs in the permanent cartilages (of the ribs and larynx, and, rarely, the epiglottis), in tendons, in the dura mater and arachnoid (the latter is very doubtful); in the eye (*Valentin*); in the ovary; in fibrous membranes (the obturator membrane); in enchondroma; in fibrous and carcinomatous growths, and in the lungs. (*Mohr.*) On the other hand, no tissue is exempt from a liability to *calcification*, except hair, nails, and epidermis.

CHAPTER VIII.

THE DENTAL TISSUES, AND THE TEETH.

SECTION I.

THE DENTAL TISSUES.

THE solid portion of the teeth within which the soft portion, or the pulp, is inclosed, consists of three distinct parts so far as the structure is concerned.

1. *The Dentine*, which constitutes by far the greatest part of the whole solid portion.

2. *The Enamel*, a peculiar structure which covers the body of the tooth, or the part which is free and exposed to view.

3. *The Cementum*, which is a layer of true bone, covering the fang and the neck of the tooth, *i.e.* the part also covered by the gum. Fig. 230 shows the relations of these three. The dentine is sometimes not covered at the neck of the tooth by the cementum.

I. THE DENTINE.

Dentine is replaced by true bone in the teeth of some of the lower animals; and its histological relationship to bone even in human teeth, is shown by the fact that an Haversian rod is sometimes seen in sections of teeth. In other respects, however, the analogy is not striking in man. A section of dentine presents under the microscope but two elements. (Fig. 231.)

1. The solid, homogeneous *intertubular substance.*
2. The dentinal tubuli.

A. The *intertubular substance* is perfectly structureless, and consists in great part of the phosphate of lime in combination with an

Fig. 230.

Fig. 231.

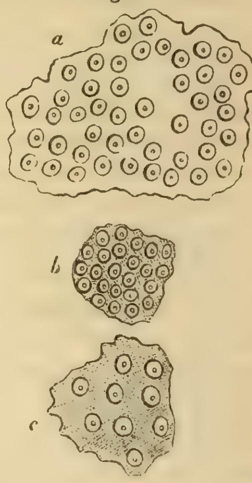


Fig. 230. Vertical section of human incisor, showing the general arrangement of its constituent parts. The dentine, the pulp-cavity, the enamel on the body, and the bone or cementum on the fang, are seen. *a.* Neck of the tooth. (Magnified 3 diameters.)

Fig. 231. Transverse sections of tubules of dentine, showing their cavities, their walls, and the intertubular tissue. *a.* Ordinary distance apart. *b.* More crowded. *c.* Another view. Human molar. (Magnified 400 diameters.)

organic substance, doubtless osteine.[1] According to Mr. Tomes, it is made up of minute granules closely united; and these pass into his "granular layer" between the dentine and the enamel. (Fig. 232, *d.*)

Chemical analysis of the solid substance of dentine gives the following results. There is more mineral matter in the molar than in the incisor teeth.

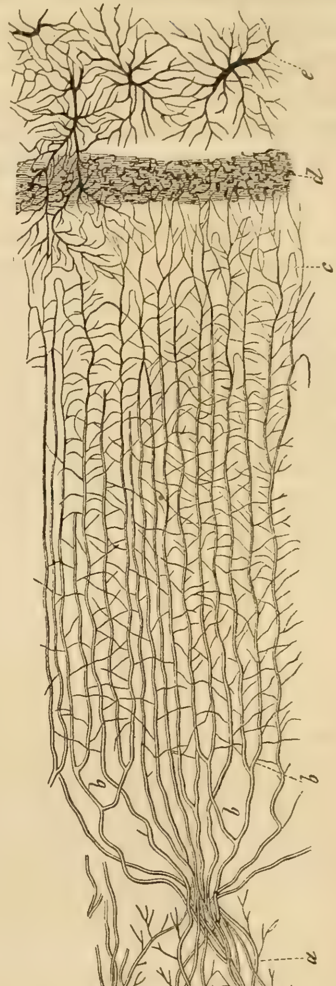
Phosphate of Lime	$64\frac{1}{3}$
Carbonate of Lime	$5\frac{1}{3}$
Phosphate of Magnesia and Soda, and Common Salt	$2\frac{1}{3}$
Organic Substance (Osteine)	28
	100.

[1] For it affords glutin on boiling.

When dentine is fractured, it presents a fibrous appearance; the fibres radiating from the centre to the circumference of the latter. The tubuli, of course, determine their direction; they being merely columns of the solid intertubular substance.

B. The *tubuli* of the dentine commence on the internal surface of the dentine, in contact with the pulp. Their general direction is upwards and outwards in the lower teeth, downwards and outwards in the upper. They average $\frac{1}{10000}$ of an inch in diameter at their commencement, but divide into many smaller subdivisions, separating at acute angles from the main trunk, and at last terminate in the outer surface of the dentine in contact with the enamel or the cementum, as the case may be. (Fig. 232.) The tubuli have a distinct and apparently very thick wall, occupying two-thirds of the diameter of the whole tube. This appearance is, however, due to the numerous short curves in the tubes, about to be described. They are naturally filled with a clear fluid, for the nourishment of the teeth, and which does not contain salts of lime, as is sometimes stated.—Hoppe finds that the walls of the tubuli do not contain gelatine.

Fig. 232.

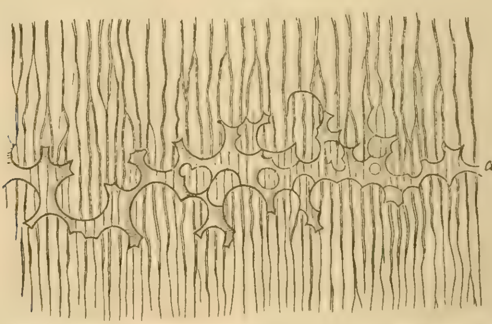


Dentinal tubuli from the fang. *a.* Internal surface of the dentine, with scattered canals. *b.* Their divisions. *c.* Terminations with loops. *d.* Granular layer, consisting of small dentinal globules at the boundary of the dentine. *e.* Bone lacunæ, one anastomosing with dentinal canals.—Magnified 350 diameters. (*Kölliker.*)

Each tubule presents two or three large curvatures and very many small ones—sometimes even 2000 within 1 line. (*Retzius.*) Se-

veral of these occurring in a thin section of dentine seen under the microscope, causes the wall to appear shaded within, and thicker than it actually is. (Fig. 231, *a*, *b*, *c*.) The branches of the tubuli are, 1st. *Principal divisions*, leaving the main trunk at acute angles; and, being repeated two to five times in the thickness of the dentine, amount to four, eight, or even sixteen in all. These terminate in a granular layer between the dentine and enamel, or between the fibres of the latter, or unite in pairs to form loops in the dentine. 2d. The *anastomosing* branches are very minute and numerous, and most so in the root of the tooth. These and the primary divisions just described, are seen in Fig. 232. Their finest subdivisions are not more than $\frac{1}{60000}$ of an inch in diameter. Seen in dried sections, the tubuli appear black; being filled with air merely, as is the case with the pores and lacunæ of dried bone. Certain projections are found in the dentine, called dentinal *globules*;[1] which are bounded by irregular spaces called *interglobular spaces*. The former are found mostly in the outer portion of the dentine, though they also occur in the deeper parts. They are globular or capitate, as represented by Fig. 233.

Fig. 233.



Section of dentine, with dentinal globules, and interglobular spaces filled with air.—Magnified 350 diameters. (*Kölliker.*)

The interglobular spaces are naturally filled by a soft substance, like tooth-cartilage (osteine), and possessing a canaliculated structure, like the dentine itself.

II. The Enamel.

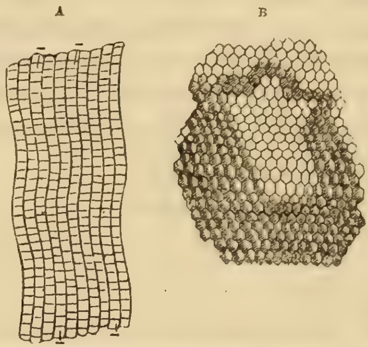
The enamel forms a layer completely investing the dentine of the body of the tooth. It is thickest on the crown and the outside

[1] Hoppe finds the globules to be distinct cells with nuclei.

and inside of the bodies of the teeth, and thinnest on the surfaces where adjoining teeth come into contact. It forms ridges on the surface and free borders of the incisor teeth—of the permanent set only.

Enamel consists of solid fibres of a prismatic form, and marked by transverse lines, whose length determines the thickness of the enamel. (Fig. 234, A.) Their inner extremity abuts upon the dentine; their general direction being nearly at right angles to the surface of the latter. In form they are hexagonal prisms, slightly undulating, and from $\frac{1}{8000}$ to $\frac{1}{5463}$ of an inch in diameter. Hence the external surface of the enamel presenting the hexagonal extremities of the fibres, resembles the simple scaly epithelium. (Fig. 234, B.) A delicate membrane covers the external surface of the enamel, named "Nasmyth's membrane," from its discoverer. This is so closely united with the latter that its existence can be demonstrated only by the action of hydrochloric acid on the subjacent enamel. It is a calcified[1] simple membrane, only about $\frac{1}{151151}$ of an inch thick. It is distinguished, however, by the great resistance it offers to chemical reagents, and its consequent appropriateness as a protection to the bodies of the teeth. Boiling water, concentrated acetic acid, hydrochloric and sulphuric acids, have no effect upon it; and nitric acid only renders it yellow. Nor is it changed by the caustic alkalies.

Fig. 234.



A. Vertical section of enamel, showing the striæ of the fibres. B. Enamel fibres seen endwise.—Magnified 350 diameters. (*Retzius.*)

The assertion by Retzius that a similar membrane exists between the inner surface of the enamel and the dentine, is probably incorrect.

Though the enamel-fibres are so firmly united, no intermediate substance can be discovered. Nor does Kölliker find the canals mentioned by Todd and Bowman between the enamel-fibres. Clefts are, however, often seen between them, especially in the middle of

[1] Dr. Huxley maintains that this is the calcified membrana præformativa of the whole pulp.—*Quarterly Journal of Microscopic Science*, vol. i. p. 149.

the thickness of the enamel; and the dentinal tubes often extend to some distance between them.

Chemical Composition.—Enamel contains but two parts of water in 1,000,[1] and is the hardest substance in the human body. It can hardly be touched by the knife, and yields sparks with steel. Enamel does not, like dentine, contain cartilage (osteine); but its organic matter—only 2 to 6.6 per cent. of the dried mass—appears like a membranous tissue, after being treated with acids. According to Lehmann, dry enamel contains 81 to 88 per cent. phosphate of lime, with 7 or 8 per cent. of carbonate of lime; and Berzelius found 3.2 per cent. of fluoride of calcium in the enamel of a human tooth. The following is Von Bibra's analysis:—

Organic matter	3.59	
Inorganic matter	96.41	
Cartilage (?)		3.39
Fat		0.20
Phosphate of Lime with some Fluoride of Calcium		89.82
Carbonate of Lime		4.37
Phosphate of Magnesia		1.34
Salts		0.88

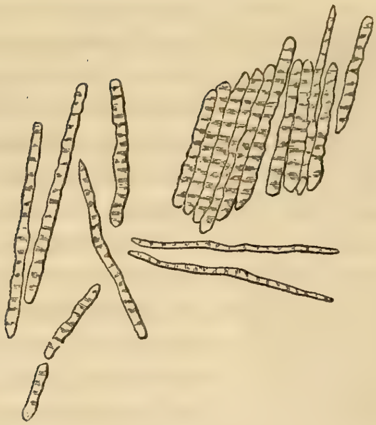
In young or developing teeth, the enamel is soft, and may be cut with a knife; and here the fibres may be easily isolated. They also show transverse striæ, somewhat like striated muscular fibre, (Fig. 235,) especially after the addition of hydrochloric acid; but a further addition converts the fibres into transparent tubes, and finally entirely dissolves the latter. It follows that neither this acid, nor any other agent that acts upon the enamel, should form a part of a dentifrice, or a wash for the teeth.

III. The Cementum.

The cementum is a layer of true osseous tissue covering the fangs and the necks of the teeth. It commences where the enamel terminates, as a very thin layer, and increases in thickness to the end of the fang. Internally it is very intimately united with the dentine, but without any intermediate substance. Externally it is very closely surrounded by the periosteum of the alveoli; but it is less firmly united with the gum. It is the softest of the three dental

[1] Robin and Verdeil, vol. ii. p. 115.

Fig. 235.



Isolated human enamel prisms, after the slight action of hydrochloric acid.—Magnified 300 diameters. (*Kölliker.*)

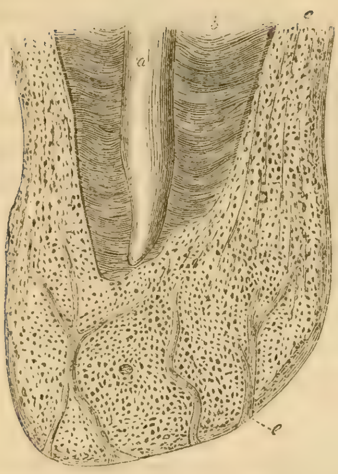
tissues, and is chemically almost identical with bone. It consists of:—

Organic matter (osteine)	32.24	
Earthy matter	67.76	
Phosphate of Lime and Fluoride of Calcium	58.73	67.76
Carbonate of Lime	7.22	
Phosphate of Magnesia	.99	
Salts	.82	
Cartilage (Osteine)	31.31	32.24
Fat	.93	
	100.00	

Like bone, the cementum consists of lacunæ and pores, and the intervening true osseous tissue. It rarely contains Haversian canals and vessels; though it has peculiar canals analogous to the tubes of the dentine, and other abnormal cavities.

The *osseous tissue* may be granular, amorphous, sometimes transversely striated, or laminated like bone. The lacunæ essentially resemble those of bone; but present great varieties of number, form, and size ($\frac{1}{2400}$ to even $\frac{1}{400}$ of an inch). The pores are unusually numerous and long ($\frac{1}{400}$ of an inch); and often resemble feathers and brushes. (Fig. 232, *e.*)

Fig. 236.



Cement and dentine of the root of an old human tooth. *a.* Pulp cavity. *b.* Dentine. *c.* Cement, with lacunæ. *e.* Haversian canals. (*Kölliker.*)

The thinnest part of the cementum contains no lacunæ, they generally commencing about the middle of the fang, where they are scattered and solitary; and becoming more numerous, and having their lacunæ freely communicating towards its extremity. (Fig. 230.)

The thick cement occurring upon old teeth, presents immense numbers of lacunæ, and very commonly, Haversian canals also, as seen in Fig. 236. In hyperostoses of the teeth, one, three, or more canals are sometimes seen entering the cementum from without, branching two or three times, and then terminating in blind extremities.

Cavities resembling the dentinal tubes are also sometimes found in the cementum; and which frequently communicate with the end of the tubuli on the one hand, and the pores of the osseous lacunæ on the other. Other cavities still have been described, but they are evidently pathological.

Remarks.—Thus it appears that the dentinal tubuli, and especially the finest subdivisions, are homologous with the pores of bone. In the latter the lacunæ are added as if expansions of the pores, to insure a freer circulation of the plasma from which the bone is nourished; while in teeth such a development would not consist with the degree of solidity and strength required in them as organs of mastication.

SECTION II.

THE STRUCTURE OF THE TEETH.

The teeth consist of—*first*, the external solid (cortical) portion; and, *secondly*, the internal soft portion, the *pulp*. The teeth are also in contact with—*first*, the gum; and, *secondly*, the periosteum of the alveoli (the cavities in which the teeth are inserted).

1. The *cortical* portion of the teeth consists of dentine, enamel, and cementum, as already shown in Fig. 230.

2. The dental *pulp* rises from the periosteum at the bottom of the alveolus, enters the fang, and fills the cavity of the tooth, and the dentinal canals; being everywhere in close adherence to the inner surface of the dentine. It is a reddish, soft, very vascular and nervous substance; and consists of mere rudimentary collagenous tissue, inclosing many dispersed, round, and elongated nuclei, and a fluid substance, with the vessels and nerves. It is invested externally by a basement-membrane, underneath which is a layer $\frac{1}{600}$ to $\frac{1}{300}$ of an inch thick, composed of many series of cells, $\frac{1}{1000}$ of an inch long, and $\frac{1}{4000}$ of an inch broad, arranged perpendicularly to the surface of the pulp like a conoidal epithelium—the *formative cells* of the *dentine*, to be described further on.

The *vessels* of the pulp are very numerous. Three to ten small arteries enter the pulp of a simple tooth, and form both internally and upon its surface a loose plexus of capillaries, $\frac{1}{3000}$ to $\frac{1}{2000}$ of an inch in diameter. There are no lymphatic vessels. (*Kölliker.*)

The *nerves* of the pulp are extremely abundant. Into every fang enters a large trunk ($\frac{1}{400}$ to $\frac{1}{300}$ of an inch), and six or more fine branches (of $\frac{1}{1200}$ to $\frac{1}{600}$ of an inch), containing fibres of $\frac{1}{12000}$ to $\frac{1}{7500}$ of an inch. Kölliker inclines to the opinion that they terminate in loops; but this is not yet demonstrated.

3. The *gum* (gingiva) is the portion of the mucous membrane of the mouth uniting the necks of the teeth and the alveolar margins of the jaw-bones. It is pale red, and rather soft, though feeling firm because resting on the bone and teeth. Upon the teeth it is $\frac{1}{2}$ to $1\frac{1}{2}$ line thick, and has papillæ of $\frac{1}{80}$ to $\frac{1}{40}$ of an inch long—in old people even $\frac{1}{17}$ of an inch. Like the papillæ filiformes of the tongue, they are covered with secondary papillæ, and a conoidal epithelium, which between the papillæ is $\frac{1}{400}$ to $\frac{1}{300}$ of an inch thick. Sometimes on its upper portions there are rounded depressions in it, $\frac{1}{15}$ to $\frac{1}{8}$ of an inch in diameter, with cells more cornified, and which may be mistaken for glands.

4. The *periosteum* of the alveolus is very intimately connected with the fangs of the teeth, having the same structure as any other periosteum, except that it is softer, contains no elastic tissue, and possesses an abundant nervous network containing many of the large nerve-fibres.

Properties and Uses of the Teeth.

The principal function of the teeth, viz. as masticatory organs, is well understood. They are also subservient to speech.

The teeth are affected by contact, by heat, cold, and chemical agents; their sensibility arising from the nerves in their pulp. It is quite delicate on the masticatory surfaces, where the smallest foreign bodies—as small grains of sand, &c.—are at once perceived when those surfaces are opposed to each other. It may also in disease become excessively acute.

Slight mechanical influences can only act by the vibration which they produce. Yet the teeth have a certain sense of locality, since we can distinguish whether they are touched internally or externally, above or below, on the right or the left side. Acids cannot penetrate the enamel, though it is not impermeable; since the nerves of the pulp are not affected by them while the enamel is entire, but are so at once when, as in the incisors, the dentine is exposed. Nasmyth's membrane is doubtless still more impenetrable than the enamel itself.

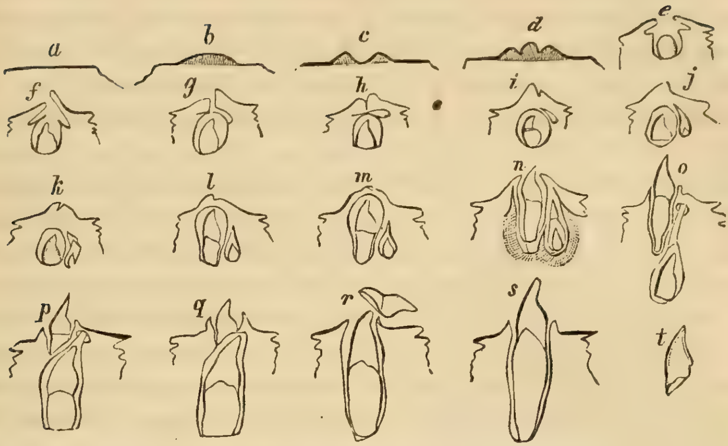
Development of the Teeth.

The first set (deciduous or milk-teeth) contains twenty, and the second (permanent teeth) thirty-two teeth. Each tooth, during its development, presents a papillary, a follicular, a saccular, and finally its eruptive state.

The development of the milk-teeth commences in the sixth week of fœtal life; twenty dental papillæ making their appearance from this period up to the tenth week, in a groove called the dental groove. Next, partitions are formed between the papillæ, and each then lies in a special follicle or cavity; and thus the papillary has merged into the following stage. During the fourth month these cavities contract, and finally close up completely, the papillæ within them at the same time assuming the forms of the future teeth; and thus the saccular stage is arrived at. A little cavity is, however, at the same time prolonged from each closed tooth-sac; these being the "reserve-sacs" in which, during the fifth month, are developed the pulps of the twenty anterior teeth of the second set. These reserve-sacs, however, gradually retract backwards, and fall into hollows in the jaw-bones; and lie at considerable depth in the latter by the time the first set make their appearance—by having attained to the final or eruptive stage.

The four stages just mentioned, and the relations of the "reserve-sacs," are shown by Fig. 237. The last are produced at their apices into a solid cord, which has erroneously been called the *gubernaculum dentis*, or guiding cord for the permanent teeth in their eruption.

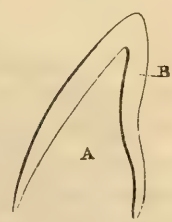
Fig. 237.



Formation of a temporary and its corresponding permanent tooth, in a sac of the mucous membrane. *a* to *d*. Papillary stage; *e* to *g*. Follicular do.; *h* to *m*. Saccular, do.; *n*, *o*. Eruptive stage; *p* to *t*. Falling out of first set.

From the manner in which the primary tooth-sacs are formed—*i. e.* by elevations of the mucous membrane around the papillæ, as shown in Fig. 237, *d*, *e*—it follows that the papilla, even after attaining to the form of the body of the future tooth, does not cause the layer covering it, of the original mucous membrane of the mouth, to come into contact with the layer which has closed over it; and therefore a space is left between these two layers—the cavity in which the enamel is formed (Fig. 238, B) from cells (the enamel pulp) contained in it.

Fig. 238.



A. The cavity containing the pulp, and the dentine when formed. B. Closed sac in which the enamel is formed.

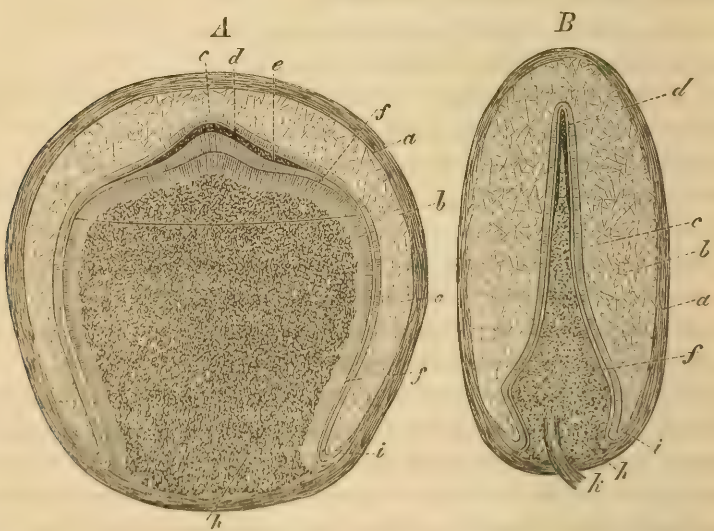
The general account of the development of the teeth is as follows: 1. A thin layer of dentine is formed from the vessels in the pulp, and which incloses the latter like a cap. This is followed by other layers within each other, the pulp itself meanwhile contracting. 2. The enamel is formed from the cells in the enamel-cavity; a thin layer being at first adherent to the outer layer of dentine, and which is followed by others till the requisite thickness is acquired, the enamel-pulp meantime gradually disappearing. 3. The body of the tooth thus being developed, the formation of the fang next takes place; the pulp of the dentine now extending into the alveolus, and dividing into two or three processes if the fang is

to be double or triple. The development of the fang from the dentinal pulp is precisely like that of the dentine in the body just described; and this process elevates the latter through the gum, and thus the eruption of the tooth takes place. The enamel, of course, covers the body only, since the enamel-sac extended only over the latter. 4. Finally, as the alveoli close around the necks of the teeth during their eruption, and afterwards more completely around the fangs, the vessels of the periosteum of the alveoli deposit a plasma from which the cementum (tooth-*bone*) is formed; and which becomes adherent to the dentine, and forms a layer becoming thicker as it approaches the apex of the fang, as before described (p. 374).

The explanation of the *minutiæ* of this process requires a knowledge of the minute structure of the dentinal pulp, and the enamel-sac and its contents. And the following statement is deemed the most accurate, in its details, of the various accounts given by different authors:—

1. The dentinal *pulp* precisely resembles, in size and form, the body of the tooth to be developed from it, consisting of an internal portion rich in vessels, and an external portion which is entirely

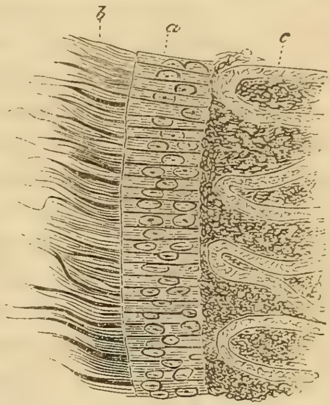
Fig. 239.



A. Tooth-sac of the second incisor of an eight months fœtus, seen on the broad surface. *a*. Dental sac. *b*. Enamel-pulp. *c*. Enamel-membrane. *d*. Enamel. *e*. Dentine. *f*. Dentinal cells. *h*. Dental pulp. *i*. Free edge of the enamel-organ.—B First incisor of the same embryo, seen on the narrow surface; letters as before. *a*. Dentinal cap in toto. *k*. Nerves and vessels of the pulp.—Magnified 7 diameters. (*Kölliker*.)

destitute of them; and is bounded by a simple membrane—the *membrana præformativa.* (*Raschkow.*) (Fig. 239.) Beneath this is a layer of elongated cells ($\frac{1}{750}$ to $\frac{1}{500}$ of an inch long, by $\frac{1}{6000}$ to $\frac{1}{2666}$ of an inch wide), with vesicular nuclei and distinct single or double nucleoli, arranged like an epithelium, though not so sharply defined internally; and next is the parenchyma of the pulp, consisting of a sort of rudimentary collagenous tissue, with many rounded or elongated nuclei, and the vessels. (Fig. 240.) The latter become very numerous at the period when the dentine begins to be formed, the most numerous perpendicular loops of capillaries, $\frac{1}{2000}$ of an inch in diameter, being in contiguity with the surface of the dentine. The nerves are developed later. Their distribution, as well as that of the vessels, in the pulp of the perfect tooth, has already been described (p. 375).

Fig. 240.



Surface of the dentinal pulp of a new-born infant. *a.* Dentinal cells. *b.* Their appendages. *c.* Vascular part of the pulp.—Magnified 300 diameters. (*Kölliker.*)

It is from the epithelium-like layer of cells that the dentine is formed; and the former seems to maintain a constant thickness by the elongation of the original cells internally (while the dentine is formed externally), accompanied by a continual multiplication of their nuclei. The parenchyma of the pulp, therefore, progressively diminishes as the dentine increases; the latter being formed in concentric layers from without inwards, like the lamellæ of the Haversian rods of bone (p. 356).

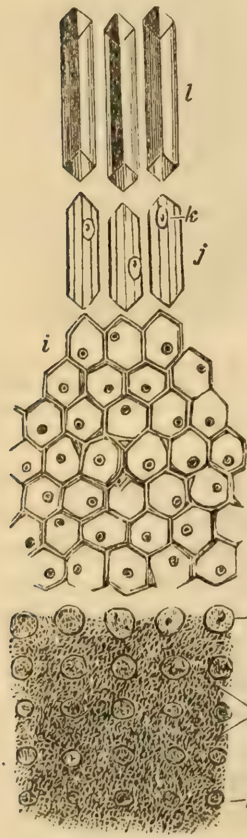
It appears that the cells just described become the solid dentine by the gradual reception of calcareous salts. The largest *tubuli* are probably the remaining unossified portions of the cavity of the cells, and are hence analogous to the lacunæ of bone. The divisions of the tubuli may result from a longitudinal division of the cells, or from a single cell coalescing with two of its predecessors. The finest lateral branches appear to be of secondary origin, and probably result from resorption of already formed dentine, like the pores of bone (p. 354).

During the ossification of the dentine, and while recently formed

and slightly hardened, the whole appears to consist of *isolated globules.* Some of them are also visible at later periods, the spaces between them being the interglobular spaces already described (p. 370). Usually, however, these spaces are filled by a deposition of dentine also, so that the latter becomes quite homogeneous and clear.

2. The *enamel-cavity* is a closed sac, and contains the enamel-pulp, which is applied to the dentinal pulp like a cap, and presents a peculiar structure. 1. Its mass consists at first of anastomosing stellate cells (Fig. 239), containing a great quantity of fluid, rich in albumen (and mucus, *Kölliker*), in its meshes. It forms a layer $\frac{1}{30}$ to $\frac{1}{18}$ of an inch thick in the fœtus of five or six months, and but $\frac{1}{75}$ to $\frac{1}{60}$ of an inch at birth; when it contains vessels in its outer third, and its network is metamorphosed into white fibrous tissue. 2. On the inside, however, of this spongy tissue lies a true cylindrical (conoidal) epithelium in contact with the dentinal pulp. This is incorrectly termed the enamel-*membrane* (membrana adamantinæ, *Raschkow*). Its cells are $\frac{1}{1000}$ of an inch in length, and $\frac{1}{6000}$ of an inch in breadth, are finely granular, and their nuclei are frequently situated at their extremities.

Fig. 241.



Formation of enamel. *h.* Primary cells suspended in fluid blastema. *g, i.* The same more fully developed, and become angular. *j.* The same becoming prismatic. *k.* The nucleus disappearing. *l.* The modified prismatic cells filled with calcareous salts, forming the fibres of enamel.

The enamel-*fibres* are formed by the complete and direct ossification of the cells just mentioned, without a previous deposit of calcareous matter in a granular form. (*Kölliker.*) (Fig. 241.) The first layer of enamel is deposited upon the outermost layer of dentine, already described, and the successive ones are formed externally to this, till the required thickness is obtained. Meantime the epithelial layer constantly remains of the same thickness

by a progressive development, while the spongy tissue proportionately diminishes, and at last entirely disappears, together with the epithelial cells; when the development of enamel is completed.

Thus the membrana præformativa (p. 379) has an epithelial layer upon both of its surfaces; the dentine being developed from the inner one, while the enamel is formed from the outer one; the vessels affording the plasma being on the distal side of the epithelial layer, from the membrana præformativa, in both cases.

3. The *cementum* is believed by Kölliker to be formed by the "portions of the dental sac lying between the pulp and the enamel-organ." We consider that the sac merely embraces the enamel-organ, and isolates it from the dental pulp; while the latter affords the epithelial layer whence the dentine is developed. Another source of the cementum must therefore be sought, and none is more probable than the periosteum of the alveoli. After the body of the tooth is completed, the pulp elongates towards the bottom of the alveolus, and thus the fang is developed from it, the body at the same time penetrating through the gum in the opposite direction. Kölliker states that the sac elongates at the same time with the pulp, and thinks that its *inner* surface affords a blastema whence the cementum is formed and deposited on the outer surface of the dentine of the fang.

It is difficult to account for the development of Nasmyth's membrane. On the supposition, however, that the membrana præformativa originally lines the whole of the enamel-cavity, it may be produced by calcification of the membrane, gluing together and protecting the outer ends of the prisms of the enamel.

The *permanent* teeth are also developed in the manner just described, from the secondary pulps mentioned on page 376, 1.

The two sets of teeth *appear* at the following ages:—

I. MILK-TEETH.

Four central incisors (the lower first),	7th month.
Lateral incisors (lower first), 7th to 10th	"
Anterior molars, 12th to 13th	"
Canine teeth, 14th to 20th	"
Posterior molars, 18th to 36th	"

II. PERMANENT TEETH.

Central incisors	8 years.
Lateral "	9 "
First bicuspid	10 "
Second "	11 "
Canines	12 to $12\frac{1}{2}$ years.
Second molars	$12\frac{1}{2}$ to 14 "
Third "	17 to 19 "

Growth of the Teeth.

The enamel does not increase in amount after the eruption of the teeth. It is, however, susceptible of some molecular changes, as its diseases indicate—especially caries. The latter is true of the dentine also, and the cementum; both of which, moreover, become thicker after the eruption of the teeth. Indeed, in old persons the pulp has sometimes entirely disappeared, and its cavity been filled with an imperfect dentine; and the cementum amounts to an exostosis (p. 374). The fissures between the enamel-prisms, the dentinal tubuli, and the lacunæ and pores of the cementum—all during life contain a nutritive fluid, and permit of nutritive changes. Since, however, perfect dentine is not colored by madder when an animal is fed with it, it is probable that these changes are far less active than in the bones. In case of caries threatening an exposure of the pulp of the teeth, the dentine very often becomes thicker within, and opposite the carious portion; the new dentine being formed to protect the pulp.

Any portion of a tooth being once removed, is never reproduced; nor is the loss at all repaired.

A *third* dentition sometimes occurs late in life, though the teeth are imperfectly developed and few in number. A tooth extracted and at once replaced, may become firm again at the end of some months (fifteen in one case).

Pathological States of the Teeth.

1. Hypertrophy of the cement (exostosis), deposits of dentine projecting into the pulp cavity, and ossification of the pulp itself, are very common results of chronic inflammation of the periosteum and the pulp. In the first, the pores become dilated, so as to form Haversian canals. (*Wedl.*)

2. A partial disappearance of the fang is quite common. The whole fang sometimes becomes transparent like horn.

3. *Necrosis* occurs where the periosteum has been removed, or the pulp has died. Here the tooth becomes rough, dark, and even black, and at length falls out.

4. *Caries* of the teeth, as in bone, is a gradual loss of substance. Its cause is not well understood. Since it always commences on the exterior, the fluids of the mouth are supposed to have an influence in producing it. There must, however, be a coincident putrefactive decomposition of the organic elements of the tooth, which becomes covered with infusoria and fungi. (*Kölliker.*) Indeed, Ficinus thinks the latter are the principal cause of caries, since it usually commences in the cracks and pits of the enamel, where undisturbed opportunity is given for these organisms to develop. The discolored spots on the enamel first lose their salts, and then break up into angular pieces. Next the dentine becomes soft, yielding not more than ten per cent. of ash (*Ficinus*), and then decomposed, and the dentinal tubuli become filled with the fluids proceeding from its decomposition; and which, reaching the pulp, may produce pain. Carious teeth contain an excess of carbonate of lime. (*Marchand.*)

5. In *jaundice* the teeth often become yellow, and in asphyxia, red: the dentinal tubuli being penetrated by the coloring matter of the bile, and the blood, respectively. In *rickets*, the teeth are not affected (p. 334). The mucus upon the teeth always contains fungi; and, on accumulating, it hardens and constitutes the *tartar* of the teeth. This consists of earthy phosphates, 79; mucus, 12.5; ptyaline, 1, and organic matters soluble in hydrochloric acid, 7.5. (*Berzelius.*)

6. Finally, teeth are sometimes developed in abnormal situations, as in ovarian cysts.

CHAPTER IX.

MUSCULAR (CONTRACTILE) TISSUE, AND THE MUSCLES.

SECTION I.

MUSCULAR OR CONTRACTILE TISSUE.

MUSCULAR tissue has recently been regarded as presenting three varieties: the elongated or fusiform contractile cell; the smooth or non-striated muscular fibre, and the striated muscular fibre. Kölliker has, however, shown that the elongated contractile cell and the smooth muscular fibre are histologically identical. He, therefore, includes both these under the name of "contractile (or

muscular) fibre-cells;" since in case of both, cells are found, more or less elongated into the form of fibres. Only two varieties, therefore, of muscular tissue need be recognized; viz., the fibre-cells just mentioned, and the striated muscular fibre.

I. The Contractile, or Muscular, Fibre-cells.

The larger fibre-cells have generally been named smooth, or non-striated, muscular fibres, and have been described as jointed fibres, presenting nodosities, as represented in Fig. 242. This is, however, their appearance, very nearly, when acted upon by water. An accurate description of them was first given by Kölliker.

The muscular fibre-cells are from $\frac{1}{600}$ to $\frac{1}{300}$ of an inch long, by $\frac{1}{6000}$ to $\frac{1}{4000}$ of an inch broad; and are composed of a soft, nearly homogeneous light-yellow substance. The nuclei are visible only when acted upon by acetic acid, and are usually long and staff-like, as seen in Fig. 243, which also shows the usual long and slender form of the cells. Very seldom a nucleolus exists in the nucleus, and the latter is always in the middle of the fibre. The substance of the cell sometimes exhibits pale, dark granules, partially arranged in rows parallel to the axis of the cell; but, in other respects, the cell, like the nucleus, is homogeneous and hyaline.

Fig. 242. Fig. 243.

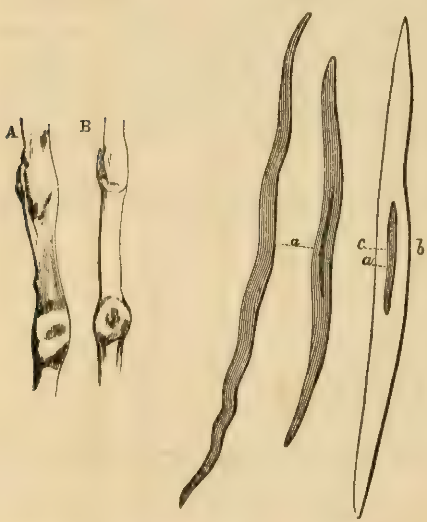
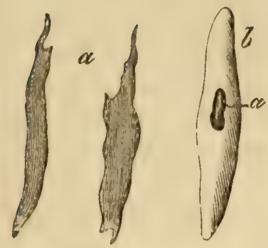


Fig. 242. A. A non-striated muscular fibre from the urinary bladder. Two of the nuclei are seen. B. A non-striated muscular fibre from the stomach. The diameter of this and the preceding fibre, midway between the nuclei, was 1-4750 of an inch. (Magnified 600 diameters.)

Fig. 243. Fusiform cells of smooth muscular fibre from the renal vein of man. *a*. Two cells in their natural state, one of them showing the staff-shaped nucleus. *b*. A cell treated with acetic acid, with a nucleus, *a*, *c*, brought strongly into view.

It is, however, doubtful if any *cell-membrane* exists.—Kölliker thinks he has seen it in some individual fibres; but Lehmann cannot demonstrate its existence chemically, and concludes that these fibres are never inclosed by a true myolemma. Should his opinion be demonstrated to be correct, the term *fibre-cell* must be again replaced by *fibre* merely. We

Fig. 244.



Human muscular fibre-cells from the innermost layer of the axillary artery: *a*, without, *b*, with acetic acid. *a*. Nucleus of the fibre.—Magnified 350 diameters. (*Kölliker.*)

shall, therefore, quite as frequently term them smooth muscular fibres.

The more common forms of the fibre-cells have been mentioned. But in the walls of the bloodvessels (Fig. 244), they are so much less elongated as sometimes to have been mistaken in the smallest, for epithelial cells; while in the alimentary canal, uterus, &c., they become what have long been called the non-striated muscular fibres of these organs. The largest of all appear in the impregnated uterus; and Fig. 245 shows one of the long cells as compared with those of Fig. 244. Rarely, also, the cells are in the form of elongated, quadrangular, or club-shaped plates, with fringed margins. (Fig. 244, *a*, and 245, *b*, *c*.)

Fig. 246.

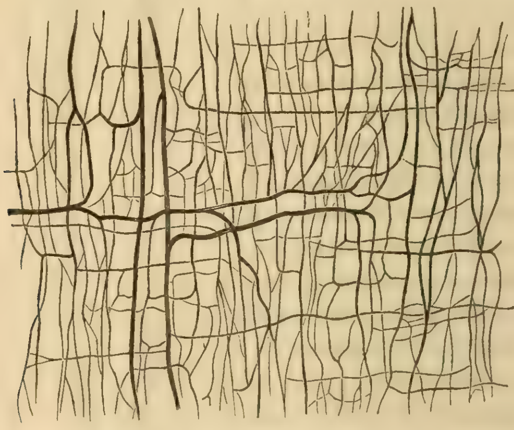
Muscular fibre-cell from the fibrous investment of the spleen of the dog.—Magnified 350 diameters. (*Kölliker.*)

Fig. 245.

Smooth muscular fibres from the gravid uterus. *a*. Formative cells. *b*, and *c*. Cells at an advanced stage from a uterus in the third month. The long fibre-cell *a*, is from a uterus in the sixth month. *c*. Its nucleus. (*Kölliker.*)

When the muscular fibre-cells exist in abundance in an organ (*e. g.* the alimentary canal, bladder, &c.), they are (1). Collected into little bundles or fasciculi, which are invested by a very delicate layer of areolar tissue—a kind of *perimysium;* and which also incloses a peculiar fluid lying among, and bathing the cells. (2). The fasciculi thus invested, are interwoven to form the required mass or thickness in the part or organ. (3). Bloodvessels are also sent in among the fasciculi to a considerable amount (Fig. 247);

Fig. 247.



Bloodvessels of the smooth muscles of the intestines.—Magnified 45 diameters. (*Kölliker.*)

while but a relatively small number of nerves is distributed to this tissue.

Chemical Composition of Muscular Fibre-Cells.

1. The *fluid* which bathes the fibre-cells in the fasciculi is identical with that contained within the myolemma of the striated muscular fibre; and will be spoken of further on in this section under the name of the *muscular juice* (p. 395).

2. The demi-solid and most important element of the fibre-cells is *musculine* (p. 98), also called muscular fibrine, and named *syntonin* by Lehmann. But since this also forms the solid substance of the fibrillæ of the striated muscular fibre, it will be described on a subsequent page (396).

Distribution of Muscular Fibre-Cells.

The smallest forms of these cells are found in the walls of the smallest arteries and veins, and the larger lymphatics. The following general account of the distribution of all their forms is from Kölliker. It should, however, be premised that this kind of muscular tissue never forms isolated *muscles* in the human body. The fibres are either scattered in the areolar tissue, or form membranous expansions—as the muscular layer of the bladder and alimentary canal; and in either case the fasciculi are either parallel, or woven into a network.

1. In the *alimentary canal*, these fibre-cells form the muscular coat (tunica musculosa), from the lower half of the œsophagus, where striated fibres are mixed with them, to the internal sphincter ani. They also form the muscular layer of the mucous membrane from the pylorus to the anus in man, and constitute the scattered fasciculi in the villi.

2. In the *air-passages*, a layer of contractile fibre-cells (smooth muscular fibres), exists in the posterior wall of the trachea, and extends through the bronchial tubes to their finest subdivisions, as a complete muscular membrane.

3. In the *urinary organs*, the smooth fibres were first found to extend throughout the male urethra by Mr. Hancock, of London. They also form two distinct layers in the bladder, and a layer extending through the ureters into the pelvis of the kidney.

4. In the *male sexual organs*, they are found in the dartos, externally to the tunica vaginalis, in the vas deferens, the vesiculæ seminales, the prostate, around Cowper's glands, and in the corpora cavernosa penis, and the subcutaneous areolar tissue of this organ.

5. The *female sexual organs* contain the smooth muscular fibres in the corpora cavernosa of the clitoris, the vagina, the uterus (where they become even $\frac{1}{50}$ of an inch long during pregnancy), in the Fallopian tubes, in different places in the broad ligaments of the uterus, in the round ligaments, and those of the ovaries. They also exist in the areolæ of the lacteal glands, and the nipples.

6. In the *vascular system*, these fibre-cells exist in the middle coat of all, and most in the smaller, arteries; and in that of most veins, and of the lymphatics, except the finest; also in the lymphatic glands of some lower animals (*Heyfelder*); and the external tunic

of many veins. In the smallest arteries they are elongated, or even round cells; which is to be regarded as a less developed form.

7. In the *skin*, this tissue appears in the form of minute fasciculi upon the hair-sacs, and which are hence called *arrectores pili* (p. 267); and in many of the sudoriparous and sebaceous follicles. Similar *arrectores* have also been found by Mr. Lister in the scalp; these little muscles being about $\frac{1}{200}$ of an inch in diameter. Their existence in the dartos, the areola and the mammilla, has already been mentioned; and Kölliker asserts that they exist in all situations where hairs occur.

8. In the eye, smooth fibre-cells form both the sphincter and the dilator (the circular and the radiating fibres) of the pupil, and the *tensor choroideæ* (ciliary muscle).

[9. The spleen in many animals has this tissue in its outer coat, and in its trabeculæ, mixed with areolar tissue; but it is not found in the human spleen.]

10. Finally, this tissue forms an incomplete coat in Wharton's duct, and in the ductus communis choledochus; while the gall-bladder is completely lined by a layer of it.

Peculiarities.—The fibre-cells of the uterus demand a special notice.

Muscular Fibre-Cells of the Uterus.

The fibre-cells of the uterus, while in its normal state, are quite short; being only $\frac{1}{6000}$ to $\frac{1}{4000}$ of an inch in length, and $\frac{1}{6000}$ of an inch wide. As it enlarges after impregnation, and finally augments to twenty-four times its original size (*Meckel*), all its histological elements undergo an increased development. But only the changes in its fibre-cells will be considered here.

Kölliker has ascertained that the walls of the uterus increase in thickness up to the fifth month of gestation, and then gradually become thinner, while its cavity increases up to the full term; and that so far as the muscular structure is concerned, there is both an enlargement of the original fibres and a production of new ones. At the end of $5\frac{1}{2}$ to 6 months after impregnation, the fibres have become $\frac{1}{250}$ to $\frac{1}{100}$ of an inch long, $\frac{1}{3000}$ to $\frac{1}{2000}$ of an inch wide, and $\frac{1}{6000}$ to $\frac{1}{4286}$ of an inch thick; instead of the dimensions mentioned above. Consequently, their length is increased from *seven to eleven times*; and their width from *two to five times*. Acetic acid brings out a distinct cell-wall inclosing these large fibres.

On the other hand, the new-formation of fibres is going on during the first half of pregnancy; when fibre-cells in all stages of development occur in great numbers. Fig. 244, *a*, represents the appearance of these during the sixth month. It appears that no new development of fibres occurs after the sixth month is completed; subsequently to that period, Kölliker could find only the colossal fibres, already described. (Fig. 244.)

After parturition, the uterus is diminished in respect to all its histological elements. But of its muscular fibres some are doubtless completely resorbed; while others become atrophied. Indeed, in three weeks after parturition, the fibres are found to be as short as in the virgin uterus. Fat-drops also appear in them; and this change can only be regarded as essentially a fatty degeneration, to a certain extent, of the fibre-cells. Their appearance at this period is seen in Fig. 248.

Fig. 248.

Smooth muscular fibres from the uterus three weeks after parturition, showing fat-drops in their interior. The four cells at the left have been treated with acetic acid. (*Kölliker.*)

Distribution of Muscular Fibre-Cells in the Lower Animals.

It is a singular fact that the smooth muscular fibre is not found at all in the Invertebrata; the fibres thought to be such, actually being allied genetically to the striated muscular fibres of the higher animals. (*Kölliker.*) The following peculiarities occur in the Vertebrata:—

1. In the *mammalia*, except man, these fibres form the genito-rectal muscle. In the orang-outang they are found upon the hair-sacs, as in man. They also occur in the spleen of many mammalia (p. 388, 9).

2. In *birds*, smooth muscular fibres exist in the skin, forming the muscles of the quill-feather; the latter having tendons of elastic tissue. In the gizzard of birds they are of a bright red color, and are united with a tendinous membrane.

3. In the *amphibia*, they exist in the iris. Also in the frog, they are found in the lungs.

4. In *fishes*, they are found in the swimming bladder. In the plagiostomata they occur in the mesentery, and in the osseous fishes in the *campanula Halleri.*

Functions of the Muscular Fibre-Cells.

The tissues thus far described, have manifested physical properties only. But muscular fibre-cells are, like the striated muscular fibres, endowed with a *vital* property, *contractility*, and the power of *contraction;* or of spontaneously shortening themselves, when excited by an appropriate stimulus. This latter is often brought to them by a nerve; but not always, nor so generally as is the case with the striated fibres. Hence they are not so abundantly supplied with the large (motor) nerve-fibres. In the alimentary canal, the muscular coat is excited to contraction more especially by the contents of the canal itself; and this is probably also true of the bronchial tubes, the blood- and lymph-vessels, the bladder and the uterus.

Hence, the motion is transmitted along a membraniform expansion of smooth muscular fibre somewhat slowly. The fibres not being bound up into parallel fasciculi to form muscles, but being interwoven, and each contracting independently of the rest—the movement of the first excites the rest in contact with it, and thus the action is propagated to a distance. This peculiarity has given to the motions of the alimentary canal the name of vermicular or *peristaltic* motion. The more or less rhythmical character of the contractions of this kind of muscular fibre, is also probably due to the anatomical peculiarity just mentioned. This is best seen in the case of uterine contractions; and also in cases of colic, and of calculus in the bladder or in the ureters.

The contractions of the smooth muscular fibres are not in the least degree under the control of volition. Those who maintain that parturition is in some instances *voluntarily* deferred (after it actually commences at the end of the full term), and then again voluntarily recommenced, are deceived by appearances which a knowledge of the reflex function of the spinal cord at once explains away.

Where a required motion is to be of slight extent, internal, not rapid, and not at all influenced by the will—it is delegated to the smooth muscular fibre. When either or all of these requirements are to be reversed, the striated muscular fibre is employed instead. It is therefore physiologically inferior to the latter. Histologically, also, it may be regarded as a lower development, as will appear.

The smooth muscular fibre manifests the rigor mortis, like the striated (p. 405).

Development of Muscular Fibre-Cells.

There is nothing peculiar in the development of muscular fibre-cells. They are formed merely by the elongation of cells originally rounded; the cell-wall disappearing (in most cases, at least) after forming the homogeneous soft substance already described—the musculine.

The nutrition of smooth muscle is probably very active, though less so than that of striated muscular fibre. Lehmann's investigations in regard to the fluid which bathes the fibres show that it has an acid reaction, and contains creatine and inosite, besides lactic, acetic, and butyric acid.

Regeneration of Smooth Muscular Fibre.

It is not certainly known whether this kind of muscular fibre is reproduced in cases of loss of substance. It is, however, probably not reproduced, but is replaced by areolar tissue.

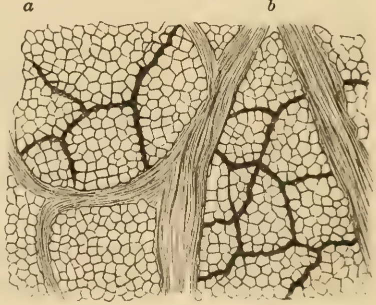
Pathological Conditions and New Formations of Muscular Fibre-Cells.

Smooth muscular fibre is liable to hypertrophy and to atrophy, like the striated form. It also becomes paralyzed like the latter, and is very liable to fatty degeneration.

Pathological new formations of this tissue occur in some cases of uterine tumors.

1. *Hypertrophy* of the smooth muscular fibre is usually of limited extent, and recognizable even by the naked eye, by the pale-red fibrillation. Occurring in the pyloric portion of the stomach, this part sometimes becomes an inch or more thick, the circular fibres being mainly increased. An areolated appearance is produced in the hypertrophied mass by the development at the same time of the areolar tissue surrounding the fasciculi, and which increases in thickness towards the submucous tissue. In certain layers of the muscular coat, flattened cells are met with, resembling epithelial cells, but having an oblong nu-

Fig. 249.



Transverse section of the hypertrophied muscular layer of the stomach, boiled in acetic acid, and dried. *a, a.* Smooth muscular fibres, divided transversely. *b, b.* Areolar tissue bundles. (*Weld.*)

cleus. These are probably the embryonic forms of the fibre-cells. (*Wedl.*) Fig. 249 shows the fibres and the connective tissue inclosing them, as seen in a transverse section. The submucous tissue is at the same time either thickened, or infiltrated with a gelatinous substance.

Hypertrophy of the smooth muscular tissue is usually attributed to a previous inflammation in the part; and Engel has shown that such a connection exists.

2. *Atrophy* of the smooth muscular tissue occurs as a consequence of old age, and of diseases attended by emaciation.

3. *Fatty degeneration* of the contents of the muscular fibre-cells is their most common form of involution;[1] much fat occurring at the same time in the interstitial connective tissue. This last form is seen most strikingly in the intestinal canal and the urinary bladder. The involution of the smooth fibres of the uterus after parturition has already been explained (p. 389).

4. *Pathological new formations* of smooth muscular fibre very rarely occur. Their new formation in the uterus during pregnancy (p. 389) must be regarded as a physiological change.

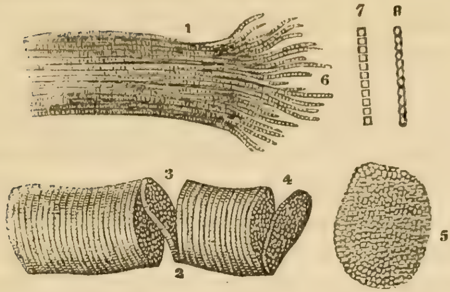
II. Striated Muscular Tissue.

It is of this tissue mainly that the muscles proper are formed; and its histological and its physiological relations are of the highest importance.

This form of contractile tissue consists of fibres marked with transverse striæ. (Fig. 250.) The length of the fibres varies exceedingly, they sometimes extending through the whole length of the fleshy part of a muscle. Their diameter varies from $\frac{1}{3000}$ to $\frac{1}{400}$ of an inch; the average being about $\frac{1}{600}$ of an inch. They are larger on the trunk and the extremities than on the head; but their size is the same in the two sexes, though the contrary has sometimes been asserted. They are about one-third as large in the fœtus as in the adult. When packed together in fasciculi, they assume the form of round polygonal prisms, as seen in a transverse section, in Fig. 263; when isolated, they approach to the cylindrical form. The striæ are, on an average, about $\frac{1}{10000}$ of an inch apart. Various hypotheses have been resorted to, to account for them; but it is believed, with Kölliker, that "it is still doubtful to what the striation is due," though it is clearly a physical and not a vital phe-

[1] This term is used to denote a pathological change or descending metamorphosis, in the histological elements of a tissue or organ. It is, however, also applied to the atrophy undergone by the uterus immediately after parturition.

Fig. 250.



Fragments of striated muscular fibres, showing a cleavage in opposite directions. (Magnified 300 diameters.) 1. Longitudinal cleavage. The longitudinal and transverse lines are both seen. Some longitudinal lines are darker and wider than the rest, and are not continuous from end to end; this results from partial separation of the fibrillæ. 6. Fibrillæ separated from one another by violence at the broken end of the fibre, and marked by transverse lines equal in width to those on the fibre. 7, 8, represent two appearances commonly presented by the separated single fibrillæ (more highly magnified). At 7, the borders and transverse lines are all perfectly rectilinear, and the included spaces perfectly rectangular. At 8, the borders are scalloped, the spaces bead-like. When most distinct and definite, the fibrilla presents the former of these appearances.—2. Transverse cleavage. The longitudinal lines are scarcely visible. 3. Incomplete fracture following the opposite surfaces of a disk, which stretches across the interval and retains the fragments in connection. The edge and surface of the disk are minutely granular, the granules corresponding in size to the thickness of the disk, and to the distance between the faint longitudinal lines. 4. Another disk nearly detached. 5. Detached disk more highly magnified, showing the "sarcous elements."

nomenon. The largest and the smallest fibres are sometimes found side by side.

Each striated fibre consists of two distinct portions: *first*, the myolemma; and, *secondly*, the myoline.

Fig. 251.

Myolemma of a torn muscular fibre of the skate.

1. The *myolemma*[1] is the envelop containing the myoline. It is merely a tube, closed at both ends, of simple membrane (Fig. 251); in or underneath which (for this point is not yet settled) nuclei are brought into view by acetic acid. (Fig. 254.) Kölliker maintains that it is not an albuminous compound, but is at least similar to elastic tissue. Certainly it may be proved to be elastic, and to fit closely upon its contents, in the normal state.[2]

[1] From μῦς, muscle, and λέμμα, coat or sheath. It is also, less accurately, named sarcolemma, by Kölliker and others.

[2] It should be here remarked that Drs. Busk and Huxley deny the existence of the myolemma as a distinct structure; affirming that it is merely the outer portion of the matrix containing the fibrillæ.

2. The *myoline* is the demi-solid substance filling the myolemma, and on the surface of this are the transverse markings before mentioned. It consists, *first*, of very minute threads, called *fibrillæ*, placed side by side, from $\frac{1}{20000}$ to $\frac{1}{5000}$ of an inch in diameter, and averaging about $\frac{1}{10000}$ of an inch; between which is, *secondly*, the *muscular juice*, to be described under the chemical composition of this tissue. Each one of these fibrillæ has its own transverse markings. Fig. 250, 1, shows a fibre splitting into its compound fibrillæ in consequence of maceration. The same cause sometimes produces a transverse cleavage of the fibres; in which case the fibre has been described as being made up of superimposed disks, instead of fibrillæ. Fig. 250, 2, represents this form of cleavage. Often, also, a longitudinal striation is apparent. The fibrillæ are not tubular in man (as in some of the lower animals), but are homogeneous throughout.

The fibrillæ are connected together by an albuminous tenacious intermediate substance of a double nature: viz., the "muscular juice" hereafter to be described; and a granular molecular substance—probably fat in part—which certain distinguished microscopists have seen lying between the extremities of the fibrillæ of a fibre which had been transversely divided. Each fibrilla is also by Todd and Bowman regarded as being composed of cells, called "the sarcous elements," as represented in Fig. 250, 5 and 6. These cells average about $\frac{1}{9000}$ of an inch in diameter; and as the alternate ones are often larger than those between them, the striated appearance of the fibrillæ has sometimes been accounted for in this way.

Fig. 252.

Anastomosing fibres from the human heart. (*Kölliker.*)

Peculiarity.—In the heart (of man, and probably of all mammals), anastomosing and dividing fibres are found. Branched fibres are also found in the human tongue. (Fig. 252.)

The striated muscular tissue is abundantly supplied with bloodvessels and nerves (both the fine and the coarse nerve-fibres), and scantily with lymphatics. (See Section II. of this chapter.)

Chemical Composition and Physical Properties of Striated Muscular Tissue.

There is reason to believe that the chemical composition of the two forms of muscular tissue is identical. C. Schmidt supposed he

had proved this to be the fact some years ago. We have to consider the composition of—

I. The muscular fluid.
II. The musculine.
III. The myolemma, containing both of the preceding.

I. The "muscular juice," as it is termed by Liebig, surrounds the fibre-cells of the smooth muscle; and is also contained within the myolemma of striated muscular fibre, where it permeates between the fibrillæ. It is easily expressed from fresh muscle, and is a decidedly acid, albuminous fluid. Its albumen may, however, be in part obtained from the blood of the muscular mass; while its large amount of caseine is peculiar to it.[1] It is from 72.56 to 74.45 per cent. water (*Von Bibra*); there being, on an average, 10 per cent. less water in muscle than in blood-serum. It also contains creatine, creatinine, inosic acid, lactic acid, and a very little fat. Scherer has also found in it acetic and formic acid; and in that obtained from the heart of the ox, he found a peculiar substance which he terms inosite or muscle-sugar. The muscular juice, like most acid fluids, also contains an abundance of potash salts, and of phosphates, while it is poor in salts of soda and in chlorides. It appears that in the horse there are twenty-nine times, and in the ox forty-six times, as much potash in the muscular juice as in the blood. There is about ten times as much chloride of sodium, on the other hand, in the blood-serum as in the muscular juice of the horse. (*R. Weber.*) While the phosphate of lime is far more abundant in the blood than the phosphate of magnesia, the reverse is true of the muscular fluid. It has been seen that the chloride of potassium is more abundant than that of sodium, and that the former is often mistaken for the latter (p. 49). About twenty-three times as much phosphoric acid exists in the ash of horse's muscle as in that of the blood-serum; more than is sufficient to form all the neutral phosphates of the alkalies.

What the precise relation is between the function of the muscular fibre on the one hand, and the chemical constitution of the muscular fluid on the other, is unknown. Liebig calculates that the striated muscles alone contain more than enough free acid to destroy the alkalinity of all the blood; and that the opposite state, in this

[1] The fluid of the smooth, however, contains more caseine and less albumen than that of striated muscle. In the latter, albumen alone is often found.

respect, of the muscular fluid and the alkaline blood circulating through the muscle, either occasions, or is occasioned by, an electrical current; which, it is implied, may be the exciting cause of muscular contraction—a proposition we hesitate to adopt. Experiments, however, point to the conclusion that muscle loses its power of contraction in proportion as its fluid is diluted.

II. After the muscular fluid is removed by pressure from the myolemma, the *solid substance* of the fibrils still remains. This is an albuminous substance, soluble in extremely dilute hydrochloric acid,[1] and is the most essential element of muscular tissue. It has already been described as *musculine* (p. 97). It exists equally in striated fibre and in the muscular fibre-cells, and the vital property of contractility doubtless inheres in it, wherever found. There is less of it within the myolemma of young than of adult animals.

III. The chemical relation which the *myolemma* bears to the inclosed cylinder of musculine has not been determined; but the substance of the nuclei inclosed in it does not differ much from musculine. (*Lehmann.*) From what precedes, there will be less musculine, in proportion, in young animals. In the contractile fibre-cells, on the other hand, the myolemma is absent, or at least is generally not demonstrable (p. 384).

Of the three distinct substances included in the analysis of muscular tissue—the myolemma, the muscular fluid, and the musculine—the last alone is an immediate principle. It is impossible to isolate the muscular tissue entirely from the bloodvessels and their contents, from the areolar tissue in the muscular sheaths, and from fat between the myolemmata. After instituting all practicable precautions, Lehmann found the following as the average result of his analyses of the muscular substance, more especially of oxen:—

	Per cent.	
Water	74.0 to 80.0	
Solid constituents	26.0 to 20.0	
	100.0	100.0

	Per cent.
Muscular fibre (musculine)	15.4 to 17.7
Gelatigenous substance (myolemmata and perimysia)	0.6 to 1.9

[1] One part to one thousand of water.

	Per cent.
Albumen (and caseine)	2.2 to 3.0
Creatine	0.07 to 0.14
Creatinine (undetermined).	
Inosic acid (do.).	
Fat, within the myolemmata and in the blood between the perimysia . .	1.5 to 2.3
Lactic acid ($C_6H_5O_5.HO$) . . .	0.6 to 0.68
Phosphoric acid	0.66 to 0.70
Potassa	0.50 to 0.54
Soda	0.07 to 0.09
Chloride of sodium (potassium) . .	0.04 to 0.09
Lime	0.02 to 0.03
Magnesia	0.04 to 0.05

The *color* of muscular fibre is due not to the blood in the vessels, but to a peculiar pigment, very similar to the hæmatine of the blood, but probably not identical with it. At least, it adheres in a free state to the fibrillæ, since it may be extracted from them by water, and coagulates with the albumen of the muscular fluid. It is not essential to contractility; since the muscles of many animals are white, though perhaps as vascular as the red muscles of other species.

Another physical property of striated muscular tissue—elasticity—will be described in the next section.

Distribution of Striated Muscular Fibre.

The striated muscular fibre is the peculiar tissue of the *muscles* properly so called; while none of the latter are ever formed of the smooth fibre, as already stated. It is, therefore, distributed:—

1. In all the muscles proper in the body, including the internal (diaphragm, levator ani, those of the eyeball, &c.), as well as those of the head, neck, trunk, and extremities.

2. In the heart and the great veins opening into it—the inferior cava to the diaphragm, and the superior cava, and the innominatæ, to the clavicles.

3. Scattered striated fibres are found in the œsophagus, and also in the round ligaments of the uterus—mixed with the smooth fibres.

Distribution and Peculiar Forms of Striated Fibre in the Lower Animals.

I. In the *vertebrata*, generally, the distribution of striated fibres is as in man. The following peculiarities are noted:—

1. In the œsophagus (with smooth fibres), of some mammalia and of the plagiostome fishes; around the contractile organ of the pharynx of the carp; and in the stomach of *cobites fossilis*, and the *intestine* of *tinca chrysitis*, and around the anal glands and Cowpér's gland in mammals.

2. In the skin of some mammalia, birds, serpents, and tailless batrachians (frog, &c.), and the tactile hairs of mammals.

3. In the lymph-hearts of many birds and amphibia; and in the right auriculo-ventricular valve, in birds, and the ornithorhynchus. Also in the inferior vena cava of the seal, close above the diaphragm.

4. In the interior of the eye in birds, and around the poison-gland in serpents.

The anastomosing fibres already mentioned, probably occur in the hearts, and the lymph-hearts of all animals. Branched fibres also occur in the tongue of all the vertebrata probably; and are found in the upper lip of the rat.

II. In the *invertebrata*, all the muscular fibres belong genetically to the striated form, whether they are clearly striated or not. (*Kölliker.*) The muscles of insects, and of the medusæ, and indeed the heart, intestine, and muscles of the genital organs, of the invertebrata generally, are distinctly striated. It is only necessary, therefore, to notice the peculiar *forms* of striated fibre in this class, which are enumerated by Kölliker.

1. Muscular tubes, with homogeneous semi-solid non-striated contents; *i. e.* the fibre is like the non-striated or smooth fibre, with a distinct myolemma; as in most of the mollusca, annelidæ, and radiata.

2. Tubes (myolemmata), containing a semifluid, homogeneous layer in contact with them, and a fluid or granular central substance frequently transversely striated or nucleated; as in Lumbricidæ, Hirudinidæ, Carinaria, and Petromyzon and Paludina in part.

3. Similar tubes, having the cortical layer of their contents transversely striated, but not divisible into distinct fibrillæ; as in many muscles of the Hirudinidæ. This form is found in the tongue, pharynx, sphincter ani, &c., of fishes even. These tubes contain a fluid in their centre.

4. Tubes precisely like the preceding, except that they have no central cavity (*i. e.* are demi-solid throughout), and break often into disks, though not into fibrillæ; as in many Articulata (*Salpæ*), and some Radiata.

5. Tubes readily breaking into fibrillæ; or precisely like the striated fibre in the Mammalia, as in certain muscles of insects.

6. Lastly, simple isolated cells, containing a transversely striated substance which fills the whole cell or only forms a thin layer upon its internal surface. These exist also, according to Kölliker, in the endocardium of the Ruminantia; constituting the peculiar cartilaginous striæ first observed by Purkinje.

Development of Striated Muscular Fibre.

The myolemma is formed originally of nucleated cells, first coalescing and then becoming absorbed where they come into contact, so as to form tubes closed at both extremities. Subsequently the original homogeneous contents of the formative cells are replaced by the fibrillæ, and thus the development of the fibre is completed. In many cases the layer of the contents next the myolemma alone gives place to the myoline; while the central part still appears like a canal within the fibrils. It has been seen that this is the permanent form of the striated fibre in some insects. After the fibrillæ are developed, and before birth, the nuclei disappear, and, with the exception of being smaller, the fibres present the same appearance as in the adult.

More particularly—in the embryo—at the end of the second month, the fibres have the form of elongated bands $\frac{1}{12000}$ of an inch broad, with nodular enlargements at different points where elongated nuclei are situated. (Fig. 253.) These bands have either a

Fig. 253.

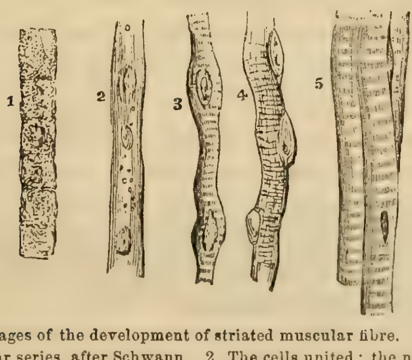


Fig. 254.

Fig. 253. Stages of the development of striated muscular fibre. 1. Arrangement of the primitive cells in a linear series, after Schwann. 2. The cells united; the nuclei separated and some broken up, longitudinal series becoming apparent—from a fœtal calf three inches long. 3, 4. Transverse striæ apparent. In (3) the nuclei are internal, and bulge the fibre. In (4) they are apparently on the surface—from a fœtal calf, two months old. 5. Transverse stripes, fully formed and dark; nuclei disappearing from view—from the new-born infant.

Fig. 254. Muscular fibre, from the adult, treated with acid—showing the nuclei. (Magnified about 300 diameters.)

homogeneous or a finely granular aspect, and, rarely, exhibit a faint trace of transverse striation. In the fourth month, they are mostly from $\frac{1}{4285}$ to $\frac{1}{2400}$ of an inch in diameter. The larger ones, though still flattened, are now of uniform width, thicker than before, transversely striated, and with fibrils capable of being isolated. (Fig. 253, 3). The musculine does not, however, yet entirely fill the myolemma, but forms a tube in contact with its inner surface, containing some of the original contents of the myolemma in its centre. Thus the musculine is the part of the fibre which is last developed. The myolemma may occasionally be raised like a very delicate membrane, by the imbibition of water. The nuclei still lie close upon the myolemma, as at first, and are rapidly multiplying; being much more numerous than at first, and often found in groups of three or four, or even six, which are sometimes arranged serially. They are all vesicular, with very distinct, simple, or double nucleoli, and frequently with two secondary cells in their interior, showing the endogenous development of the nuclei from the original ones. At birth, the fibres are $\frac{1}{2142}$ to $\frac{1}{1904}$ of an inch in diameter; are solid, rounded, polygonal, and longitudinally and transversely striated, as in the adult; and the nuclei have disappeared. (Fig. 253, 5.)

Thus the myolemma represents the sum of the membranes of the original coalesced cells, and the fibrillæ are the altered contents of the original tubes (myolemmata). A fibre, therefore (and not a fibrilla, as Leidy and Reichert maintain), is histologically analogous to a contractile fibre-cell (p. 390); and the latter may be regarded as a lower development of the former.

The *growth* of the striated muscular fibre, must be referred principally at least, to increase in the number of the fibrillæ, and of course of the size of the myolemma containing them. In other words, each fibre grows larger, while there is no proof that new fibres are formed even after the middle period of intra-uterine life. Thus the fibres are about five times as thick in an embryo at four or five months as at two months; and three or four times as thick in the new-born infant as at the period first mentioned. In the adult, they are perhaps five times as thick as at birth. Donders thinks the number of the *fibrillæ* is the same in the young and the adult animal, and that they only increase in size; they being $\frac{1}{4}$ to $\frac{3}{8}$ smaller in the calf than in the ox. Kölliker, however, relying on Harting's assertion that they are but little thicker in the adult than in the fœtus, believes their number increases in each fibre.

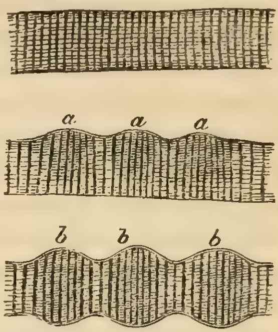
Striated muscular fibre is not *regenerated*; and wounds in muscles heal simply with a tendinous callus.

The development of the accessory parts of muscles (tendons, &c.) is included under that of the muscles as distinct organs (Section II.).

The Function of Striated Muscular Fibre.

Striated, like smooth muscular fibre, is distinguished by the vital property of *contractility;* but, unlike the latter, the former may be made to contract voluntarily. The direct result of the contraction of the striated fibres in a muscle, is a shortening of it; which approximates its two extremities, and at the same time produces motion of one of the parts (usually a bone) to which it is attached. But we have here to speak of the contraction of single fibres only.

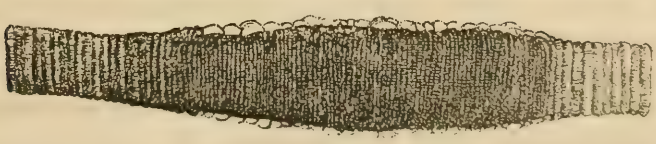
Fig. 255.



Stages of contraction seen in muscular fibre of the skate. The uppermost figure shows its state previous to the commencement of active contraction. *a*, *a*, *a*. Successive "waves" of contraction seen moving along one margin of the fibre; marked by a bulging of the margin, an approximation of the transverse stripes, and a consequent darkening of the spots. *b*, *b*, *b*. Similar "waves" still moving along the fibre, but engaging its whole thickness.

If a striated fibre be observed while contracting, it is seen to become shorter and thicker; the striæ approach each other (Fig. 255); and sometimes the muscular fluid, forced out from between the fibrillæ, causes the myolemma to project at points, forming bullæ, as seen in Fig. 256. It is scarcely profitable to inquire what causes the shortening of the fibre, by the approximation of its disks, since it is a *vital* act; and the merely chemical explanation suggested by Liebig is altogether unsatisfactory. But that the musculine alone is endowed with the property of contractility, is sufficiently certain.

Fig. 256.



Muscular fibre of Dytiscus, showing the contracted state in the centre, the striæ approximated, the breadth of the fibre increased, and the myolemma raised in bullæ on its surface.

It is, however, the fact that ordinarily (and perhaps always) the immediate stimulant to contraction of the striated fibres is an influ-

ence imparted by a nerve distributed among them in the muscle. Electricity, galvanism, and a variety of other agents, will, however, excite it in muscles in the living body, or in portions removed from the same. In fact, the only way in which a muscular fibre can react vitally when acted upon by any external agent, is by contracting, since this is its peculiar vital endowment. The shortening also occurs instantaneously.

The *chemical changes* which attend the contraction of a fibre are not all understood. There is, however, reason to believe that the substance of the fibrillæ—the musculine—alone is concerned actively in the contraction, and alone undergoes chemical changes during it. It is also certain that the contact of oxygen is necessary to the contraction of a fibre, and that during it carbonic acid gas is formed within the fibres, and not in the bloodvessels distributed among them; while the temperature of the muscle also rises two or three degrees. (*Becquerel and Breschet.*) Hence the contractility of a set of muscles is lost if their supply of blood is cut off.

The extent to which a fibre may become shortened during contraction seldom if ever exceeds two-thirds of its length; or reduces the fibre to one-third of its original length. Some give one-third as the usual amount of shortening, the fibre then being two-thirds its original length. Kölliker states that the average shortening is three-fourths (*i. e.* down to one-fourth), and in powerful muscles even five-sixths (or down to one-sixth), of the original length. Hassall estimates the shortening at one-third to one-half only, of the original length.

In ordinary circumstances, not all the fibres in a muscle contract simultaneously; but each contracts for an instant and relaxes, while of the rest some are contracting at the same time, and others follow these in their turn. It is probably only when the most powerful muscular efforts are made that all the fibres of a muscle contract at once.

The absolute extent of motion (or shortening) produced by a striated fibre will, therefore, depend on its length; while its contractile force or strength will depend on its size, it being stronger in proportion to the area of the transverse section of the musculine (and of the fibrillæ) within its myolemma.

So long as a muscular fibre is in a state of perfect nutrition, it also manifests a slight but constantly exerted tension, called tone or *tonicity*, and in regard to the nature of which very diverse opinions

have been held. This property, however, diminishes in proportion to the duration of the contractions of the fibre, and is not again recovered till the fibre has had time to rest. It does not appear to depend upon the constant influence of the spinal cord, or on any other merely nervous agency. But that it depends merely on a healthy nutrition, and is the expression of the fitness of the muscle for action, is rendered quite probable from the effect of rest in restoring it, and from the loss of tone and the flabby state which are consequent upon long-continued exertion. This tensive force being constantly exerted in ordinary circumstances, produces the somewhat flexed position of the limbs in a sound sleep; since the flexors are so inserted as to act to greater advantage than the antagonizing extensors, though actually less strong than the latter. It also accounts for the habitual closure of most of the sphincter muscles, and the deviation, to one side, of the tongue or of the mouth when the muscles of the opposite side are paralyzed. In all similar cases, the sound muscles are not in a state of incessant *contraction*, as often asserted; but merely in a state of tension, and at rest, while the antagonizing muscles have lost both their contractility and their tonicity.

The use of the *muscles* is inferred from the preceding remarks, and will be particularly specified in the second section of this chapter.

Modifications of the Contractility of the Striated Muscular Fibre.

1. An increased or an irregularly acting contractile force of the striated fibres constitutes *spasm*. If the contraction is constant, it is termed *tonic* spasm (as tetanus, trismus, &c.); if irregular and intermitting, it is *clonic* spasm, or convulsions (epilepsy, chorea, &c.).

2. A loss of contractility constitutes *paralysis*, and in which, if complete, all motion is of course impossible.

3. The *rigor mortis* is that tonic spasm of all the muscles which usually comes on several hours after death.

It is in some rare cases entirely absent—as after death by lightning or by asphyxia. It may also be so slight, and last so short a time, as to escape observation. It affects the muscles in the following order: those of the neck and lower jaw; those of the trunk; and those of the lower and the upper extremities. It departs also in the same order.

It affects all the muscles with nearly the same intensity; the

flexors, however, being usually more contracted than the extensors, flexing the fingers on the palm, and the forearm on the arm, and closing the mouth if the lower jaw had previously fallen. It is equally intense even in muscles paralyzed by hemiplegia, provided they have not become much atrophied.

The period elapsing after death before its supervention, and its duration, are variable. It usually occurs within seven hours, and continues from twenty-four to thirty-six hours. But twenty or even thirty hours may elapse before it supervenes, and it may be prolonged through several days. Its departure is immediately followed by decomposition. When early developed, it lasts but a short time, and *vice versa*. Any cause which has exhausted the muscular energy before death, causes the rigor mortis to come on and to pass off sooner—as a protracted disease, or violent efforts. Indeed, powerful stimulation of the muscles by electrical currents, immediately after death, also produces the same effect. The following results were obtained by M. Brown-Séquard, who experimented on four rabbits, reserving a fifth for comparison:—

1. Not electrized; rigidity occurred in 10 hours, and remained 192 hours.
2. Feebly electrized; rigidity occurred in 7 hours, and remained 144 hours.
3. Somewhat more electrized; rigidity occurred in 2 hours, and remained 72 hours.
4. Still more strongly electrized; rigidity occurred in 1 hour, and remained 20 hours.
5. Submitted to a powerful current; rigidity occurred in 7 minutes, and remained 25 minutes.

In animals hunted to death, the rigidity comes on very early, and lasts but for a short time.

On the other hand, M. Brown-Séquard found that the rigor mortis is deferred by injecting the muscles with fresh blood, after death. Stannius also found it to occur even in living animals, if the supply of blood to a group of muscles is entirely cut off. After death from typhus, the limbs sometimes stiffen within fifteen to twenty minutes. It also occurs rapidly in infants, and in old people.

It should, however, be remembered that in certain states of the muscular and nervous systems, a tetanic rigidity immediately en-

sues after death, and which may be mistaken for the rigor mortis. This, however, is in a few hours succeeded by a state of relaxation of the muscles, and then the ordinary rigor mortis supervenes.

A knowledge of all the facts connected with this subject is essential in certain judicial investigations; in regard to which the works on medical jurisprudence may be consulted. Its cause is not understood. It does not, however, depend upon the diminished temperature of the dead body, since it often occurs while the latter is still warm; nor is it produced by the coagulation of the blood, though in those cases of death in which the blood does not coagulate (p. 94, vi.), the rigidity usually manifests itself least. We can hardly say more than that the rigor mortis is the last vital act of the muscles, as the coagulation of the blood is of the fibrine (p. 93, III.).

It should be here added, however, that the rigor mortis is equally, if not more remarkable in the smooth muscular fibre. The arteries contract so as to force their blood into the venous system; which almost invariably occurs a few hours after death. They then enlarge as the rigidity passes off, and become quite flaccid. Hence the old physiologists believed that the arteries naturally contained not blood, but air, and named them accordingly.[1] The alimentary canal, the bladder, and the bronchial tubes are also, for a time after death, contracted in a similar manner; and the post-mortem contraction of the parturient uterus in patients who had died undelivered, has been known in several instances to expel the fœtus.

The "concentric hypertrophy" of the heart, as it was formerly called (this organ being thicker than usual and smaller), has been shown by Mr. Paget to be merely the state of cadaveric rigidity which usually occurs in that organ. The ventricles become rigid and contracted within an hour or two after death; and usually remain in that state for ten or twelve hours (sometimes twenty-four or thirty-six even), when they again relax and become flaccid.

Of the *lower animals* the rigor mortis occurs most rapidly in those possessing the greatest muscular irritability (*e. g.* in birds), and *vice versa*—slowest, therefore, in reptiles and fishes.

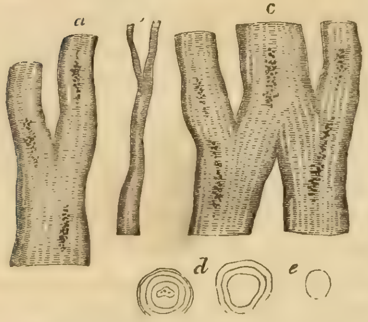
Pathological Conditions and New Formations of Striated Muscular Fibre.

1. *Hypertrophy* scarcely occurs except in case of the tongue, heart, and certain respiratory muscles; though the increased development

[1] From ἀήρ, air, and τηρέω, to keep or hold—an air-holder.

induced by exercise is constantly seen. Mere increased size of the original fibres may account for the effects of exercise, but there is probably a growth of new fibres in the former case. Wedl asserts that the number of fibrillæ in the fibres is increased in pathological hypertrophies; and in hypertrophied heart the fibres are of a tawny or rusty-brown color, soft, and sometimes anastomosing, as seen in Fig. 257. It is also certain that in hypertrophied muscles the connective tissue between the fibres sometimes becomes hypertrophied.

Fig. 257.



Muscular fibres in a hypertrophied heart. *a.* A subdividing striated fibre, with dirty yellow pigment molecules in the myolemma. *b.* A slender dichotomous fibre. *c.* Anastomosing fibre.—*d.* Laminated, and *e*, smooth, colloid-cell.—Magnified 350 diameters. (*Wedl.*)

2. *Atrophy* of muscles is very common, and occurs in old age, from lead-poisoning, from paralysis (especially of the tongue), and from the development of cancer, fibrous tumors, fat, &c., in the substance of the muscles. All causes of general emaciation also produce it.

In extreme old age, Kölliker found the fibres small, sometimes not more than $\frac{1}{3000}$ to $\frac{1}{1500}$ of an inch in diameter; mostly without striæ, and with the fibrillæ indistinct; and often containing yellowish or brown granules $\frac{1}{12000}$ of an inch in diameter, in large quantity, and very many vesicular nuclei with nucleoli, together with a clear fluid.

In *paralyzed* muscles, Valentin found the transverse striæ were indistinct, or had actually disappeared, and could not be made to appear by water, alcohol, &c.; while the longitudinal striæ remained, but resembled those of macerated muscle. Subsequently the altered fibres disappeared in part, and were partly replaced by fat.

Fig. 258.

Atrophy of striated muscular fibre. *a.* A fibre torn across. *b.* Fibrillæ hanging out.—Magnified 350 diameters. (*Wedl.*)

In a *pectoralis major* atrophied by cancer, Kölliker noticed conditions similar to those in old age. He also found cells in many of the fibres exactly resembling the so-called cancer-cells. Wedl states that in atrophy some of the fibrillæ undergo absorption. The fibre also manifests a diminished cohesion, and is easily lacerated; the myolemma being easily torn as well as the myoline within. (Fig. 258.)

3. In *fatty degeneration* of muscles, minute fat-globules are developed within the myolemma, in place of the fibrillæ, which gradually disappear. The fat-drops also accumulate between the fibres;

and, finally, the latter to a greater or less extent disappear, and give place to areolar tissue and fat-cells. (Fig. 259.)

Fig. 259.

Fatty degeneration of the heart. A. Fibres taken from the columnæ carneæ of the mitral valves of a woman æt. 30; the fatty degeneration was scarcely observable in the ventricle, where the fibres still retained their striæ. B. An extreme case of fatty degeneration, showing an entire replacement of the myoline by oil globules, still retaining a linear arrangement. From the right ventricle of an old gentleman who had Bright's disease of the kidney and pulmonary phthisis, and was affected with fits during the last two years of his life.

4. The condition of the fibres in *emaciated* muscles is unknown. Donders found them more slender in a frog which had fasted eight months; which he attributed mainly to the removal of the muscular fluid from between the fibrillæ.

5. *Paleness* of the muscles is common in dropsy, chlorosis, paralysis, lead-poisoning, old age, &c.; the coloring matter being, perhaps, converted into the numerous brown and yellow granules before mentioned as appearing within the myolemma.

6. *Softening* often accompanies paleness. In the former, the fibres exhibit no transverse striæ nor fibrils; and readily break up into numerous particles, or even into a pultaceous mass.

7. Muscular fibres *ruptured* in tetanus, present numerous nodular enlargements, in which the transverse striæ are very closely approximated; and between them either rupture of the fibrillæ, or at least a considerable stretching and disorganization of them. (*Bowman.*)

8. *Concretions* sometimes exist in muscles. The state of the fibres has not been investigated.

9. True *bone* is also sometimes formed in muscles subjected to prolonged exercise, as the deltoid and some others. The precise changes in the fibres in this case also are unknown.

10. Of *parasites* in muscles, the *Cysticercus cellulosa*, and the *Trichina spiralis* are to be mentioned. These are contained in distinct cysts; and which are situated between the fibres.

11. Rokitanski found a *new formation* of the striated muscular fibres in a tumor of the testis of a person eighteen years old; and Virchow also once detected it in an ovarian tumor.

SECTION II.

STRUCTURE OF THE MUSCLES.

The muscles consist of striated muscular tissue, areolar tissue, vessels, and nerves; and all the longer fusiform muscles (as of the extremities) contain a considerable amount of the white fibrous tissue also.

The last-mentioned muscles may each be divided into—*first*, the aponeurosis of origin; *secondly*, the tendon by which they are inserted into the bone or other organ to be moved by them; *thirdly*, the belly, or intermediate portion. (Fig. 260.) Each of these will be separately described.

Fig. 260.

The aponeurosis, belly, and tendon of the fusiform muscles (flexors) on the anterior aspect of the forearm. 5. The flexor carpi radialis; its aponeurosis of origin is seen at its upper extremity, next its belly above the figure 5; and the tendon below the latter.

Fig. 261.

Transverse section of the tendon of a calf. (Magnified 20 diameters.) *a.* Primary fasciculus. *b.* Secondary fasciculus. *c.* Nuclear fibres not quite in transverse section, but appearing as little streaks in the former. *d.* Interstitial connective tissue. (*Kölliker.*)

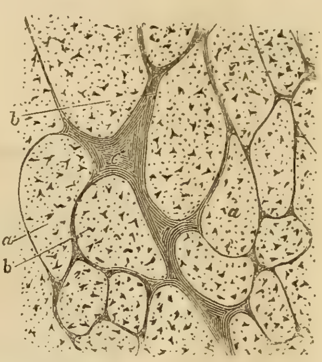
1. The *aponeuroses* are composed of white fibrous tissue, and are generally flattened into the form of a membrane. Their structure has already been specified (p. 278, 2).

2. The *tendons* are also cords of white fibrous tissue, like the

ligaments, and containing very few elastic fibres. The fasciculi of the collagenous tissue are inclosed in sheaths of areolar tissue, which thus forms delicate dissepiments penetrating the substance of the tendons, as shown in Fig. 261; then several of the primary fasciculi (five to ten) are collected into large bundles—the secondary fasciculi. Finally, the vessels are distributed in the spaces between the fasciculi (Fig. 176); elastic fibres are also sent into them, and the whole is invested by a sheath of areolar tissue (p. 278, 1).

The elastic fibres require a particular description, however. In a transverse section of a tendon, their extremities are seen as dark points in the substance of the fasciculi, at constant distances of $\frac{1}{1700}$ to $\frac{1}{1500}$ of an inch apart, over the whole section; and being $\frac{1}{24000}$ to $\frac{1}{12000}$ of an inch in diameter. (Fig. 262.) These are also connected together in various directions by other finer fibres, $\frac{1}{60000}$ to $\frac{1}{30000}$ of an inch in diameter, so that there is in tendons an elastic network penetrating and entwining the collagenous tissue. These are sometimes seen in transverse sections, as lines radiating from the coarser points before mentioned.

Fig. 262.



Tendon of the tibialis posticus (man). *a.* Primary fasciculi. *b.* Thicker nucleated fibres. *e.* Interstitial connective tissue.—Magnified 60 diameters. (*Kölliker.*)

Besides, the tendons in certain situations contain cartilage-cells, as well as even fat-cells—as in the intercostal muscles, the masseter, &c.

The glistening appearance of the tendons depends upon their transversely banded aspect, as seen under the microscope; and the latter is produced by the numerous curves in the fibres, which correspond with each other throughout the fasciculus. The curves are doubtless produced by the elastic tissue in the fasciculus, and therefore at once disappear when the tendon is stretched.

The tendons consist of 62.03 per cent. of water (*Chevreuil*); they containing considerably less, therefore, than the muscular tissue (p. 396).

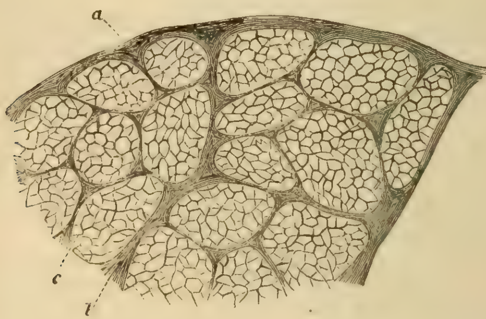
3. The *belly* of the fusiform muscles, and the red portion of all others, is the only portion that presents a peculiar structure, as alone containing the muscular tissue; and this, therefore, will be particularly described. It consists of—

1. The striated muscular fibres.
2. Areolar tissue.
3. Bloodvessels, lymphatics, and nerves.

The last three will be described after the two preceding topics, and the connection of the tendons with the bones and the muscular fibres, have been disposed of.

1. The *striated muscular fibres*, already described, are collected together into bundles (fasciculi), each inclosed in a sheath of areolar tissue (internal perimysium[1]); these are collected together into larger, and the latter into still larger, bundles—secondary and tertiary fasciculi; and finally the whole is inclosed in a sheath of areolar tissue—the *external perimysium*. These parts are seen in a transverse section of a muscle, Fig. 263. The primary fasciculi are

Fig. 263.



Transverse section from the rectus capitis anticus major of man. *a*. External perimysium. *b*. Perimysium internum. *c*. Single fibre, and muscular fasciculi.—Magnified 350 diameters. (*Kölliker*.)

$\frac{1}{72}$ to $\frac{1}{24}$ of an inch thick. The secondary and the tertiary vary extremely in their dimensions. They are very evident to the unaided eye in the coarser muscles, especially the glutæus maximus and the deltoid.

The direction of the fibres sometimes corresponds with that of the tendon, and sometimes meets the latter at an acute angle (semitendinosus, &c.). In the former case they are longer than in the latter; sometimes, indeed, extending through the whole length of the belly of the muscle—as in the sartorius.

2. The *areolar tissue* constituting the muscular sheaths (perimysia)

[1] From πέρι, around, and μῦς, a muscle. All the interfascicular areolar tissue taken together is sometimes called the internal perimysium.

both supports and transmits the vessels and nerves, and also incloses and supports the muscular fibres while in action. The external perimysium contains more elastic tissue than the internal; and, in estimating its function, it may be regarded as a semi-elastic membrane. Liebig found about 5.6 per cent. of the muscle to be connective tissue; Von Bibra but 2.2 per cent. There is proportionally more in the calf than in the ox.

In all muscles, but especially the laxer in structure, a certain number of adipose cells also are found in the areolæ of the perimysia; and these frequently contain beautiful crystals of margaric acid (p. 298). In fat persons these cells are quite abundant among the primitive fasciculi even.

Fig. 264.

A muscular fibre, (*a*), from one of the internal intercostal muscles of man, continuous into a tendinous fasciculus (*b*), into which it passes without any defined limit.—Magnified 350 diameters. (*Kölliker.*)

Connections of the Tendons at their Extremities.

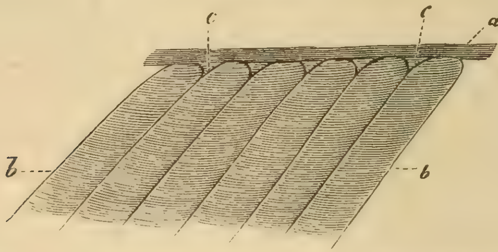
The tendons are connected at one extremity with the belly of the muscle (or the part containing the muscular fibres), and at the other with the bones or other parts moved by the muscles.

I. The tendons are connected with the *muscular fibres* in two ways: 1. When the latter lie in the direction of the axis of the muscle, and thus extend through the whole length of the belly of the latter, they pass directly into the fibres of the white fibrous tissue in the tendon, in such a way that there is no sharply defined limit between the two tissues; the tendinous fibre being nearly equal in size to the muscular, and appearing to be actually continuous.[1] (Fig. 264.) 2. But when the muscular fibres join the tendons at an acute angle—as in the penniform muscles—the microscopic conditions are entirely different; there being an abrupt limit between the two tissues. Here the muscular fibres end neatly in an obliquely truncated extremity, with a projecting surface, slightly conoidal, or sometimes perceptibly attenuated, and always rounded; and

[1] Dr. Leidy has described a double spiral arrangement of the tendinous fibres around the myolemma.

attached at a more or less acute angle to the surfaces of the tendons and aponeuroses, and on the borders of the former. (Fig. 265.)

Fig. 265.



Disposition of the muscular fibres at their oblique insertion into the tendon of the gastrocnemius of man. *a*. A portion of the tendon cut longitudinally. *b*. Muscular fibres, with slightly conical or truncated extremities, affixed in small depressions on the inner aspect of the tendon; with the sheath of which the perimysium internum (*c*) is connected.—Magnified 350 diameters. (*Kölliker.*)

Still, the connection is of the most intimate kind; the extremities of the fibres being inserted into minute pits in the surface of the tendon, while the perimysia interna are continuous with the areolar sheaths of the fasciculi of the tendon. In muscles which have been boiled, the sacciform blind extremity of the myolemma may be seen. In no case does Kölliker find the tendinous fibres connected with the myolemma merely, as stated by Reichert.

The preceding arrangement obtains whenever muscular fibres and tendons meet obliquely (all penniform and semi-penniform muscles), and whenever tendons of insertion commence as membranous expansions (soleus, gastrocnemius, &c.). And even where tendons and aponeuroses join the muscle in a straight line, there is a greater or less number of fibres which are connected in this way, though most undergo a transition, as described at the commencement of the preceding paragraph.

II. The tendons are connected, at their *distal* extremity or insertion, with bones, cartilages, fibrous membranes (sclerotica, tendinous fasciæ), ligaments, and synovial membranes (subcruralis, &c.). The aponeuroses of origin are also connected with the same parts; and their manner of connection is therefore the same as that of the tendons, to be described.

The tendons are connected with the bones and cartilages, either first, *directly;* or, secondly, *indirectly*—*i. e.* through the intervention of the periosteum and the perichondrium.

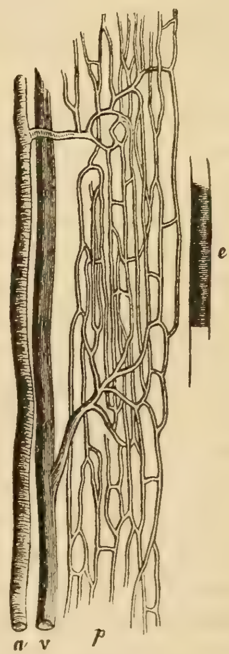
1. In the former case, the periosteum is entirely wanting where the muscle is inserted, and the tendinous fibres and fasciculi rest at

an acute or a right angle directly on the surface of the bones, being blended with all its elevations and depressions. Close to the bones, the tendons frequently contain delicate isolated cartilage-cells. (Fig. 224.) Sometimes the tendinous fibres are, next the bone, entirely incrusted with calcareous salts, in the form of granules (ossified). This kind of direct connection obtains in the tendo-Achillis, the tendons of the quadriceps femoris, pectoralis major, latissimus dorsi, deltoid, psoas, iliac, glutæi, &c. (p. 346).

2. In case of indirect connection of the tendons, their fasciculi and fibres are continuous with those of the periosteum, fasciæ, fibrous membranes, &c., respectively.

The insertion of muscles into the areolar tissue of the skin and mucous membranes, without the intervention of tendons, should be alluded to here. This is best seen in the tongue and the facial muscles of mammals. Here the muscular fasciculi lie in the subcutaneous areolar tissue, maintaining the same diameter till they nearly reach their insertions.—Then they divide into several branches, each tapering to a conical extremity, or dividing into a number of delicate pointed processes. In either case, the fibres gradually or suddenly lose their striation, and pass into the nucleated bands of the white fibrous tissue. No myolemma can be seen in the branched ends of the muscles, but the white fibrous tissue is directly continuous with the matrix of the muscular fibres.

Fig. 266.



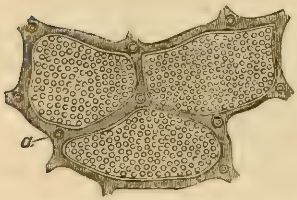
Capillaries of a small fasciculus of muscular fibres from the neck of the dog. *a*. Terminal twig of the artery. *v*. Terminal twig of the vein. *p*. Plexus of capillaries. *e*. Single muscular fibre, to show the relative size and direction of those to which the capillaries, here represented, are distributed.

The Vessels of the Muscles.

The arterial trunks reach the muscles in an oblique or transverse direction, and then subdividing, run in the perimysia interna in an arborescent manner, and at an acute or obtuse angle, so that every part of the muscle is supplied by them. The minutest arteries and veins usually run parallel to the muscular fibres, between which they form a plexus, so characteristic as never to be mistaken after being once seen. (Fig. 266.)

The longitudinal vessels of the network lie between the fibres, and the transverse ones unite in various ways with the former. Thus each separate fibre is surrounded on all sides by minute vessels, and hence abundantly supplied with blood. The longitudinal vessels are seen in a transverse section of a fasciculus (Fig. 267) lying in passages in the internal perimysium.

Fig. 267.



Transverse section of three fibres of the dried pectoral muscle of the teal (querquedula crecca), treated with weak citric acid; showing the round refracting particles separated from one another. The cut edge of the tubular sheath (internal perimysium) of each fibre is also seen, as well as the capillary vessels (a) in the intervals.

The capillaries of muscle are among the smallest in the human body, their diameter being often less than that of the blood-corpuscles themselves. In the pectoralis major, when filled with blood, they measure $\frac{1}{6000}$ to $\frac{1}{4000}$ of an inch; and, when empty, $\frac{1}{7500}$ to $\frac{1}{6000}$ of an inch. (*Kölliker.*)

The tendons present no bloodvessels in the innermost portions, and the smallest are entirely non-vascular internally. The latter, however, present vessels in the sheath inclosing them; and the largest have vessels both in the sheath and in the deeper layers. (Fig. 176.)

Very few *lymphatic* vessels are found in the muscles. Indeed, the smaller (omo hyoid, subcrural, &c.), have none at all, either in their substance or upon their surface; and among the largest muscles, it is only in some that solitary lymphatics, $\frac{1}{60}$ to $\frac{1}{48}$ of an inch n diameter, are seen accompanying the bloodvessels. It is probable that these do not run among the fasciculi, but in the more vascular perimysia between the larger and laxer subdivisions; and especially when the latter contains adipose tissue, and is therefore soft, as in the glutæus, and in the superficial layers of the muscles.

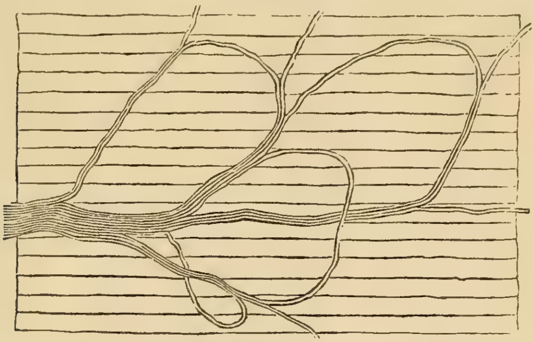
No lymphatics have yet been found in the tendons, aponeuroses, or the synovial capsules of the muscular system. They may, however, exist in the areolar tissue under the latter; as in the subserous areolar tissue of the joints.

Nerves of the Muscles.

The nerves of the muscles come into contact with the fibres only at a few points comparatively, and not throughout their length. The trunks divide pretty suddenly on entering the muscles, into several anastomosing subdivisions, which give off still smaller loops

inclosing the fasciculi, and passing among the individual fibres. (Fig. 268.) Whether there are also *free* terminations of the nerve-fibres in man, besides these loops, such as exist in the lower animals, is not certainly determined.

Fig. 268.



Form of the terminating loops of the nerves of the muscles.

The trunks entering the muscles are composed mostly of the thick (medullated) nerve fibres; there being only twelve of the finer, on an average to one hundred of the larger. (*Volkmann.*) In the interior of the muscle they, however, become smaller; so that the fibres of the terminal plexus are only $\frac{1}{12000}$ to $\frac{1}{4800}$ of an inch in diameter. Sometimes the gradual attenuation can be seen under the microscope, showing that sometimes at least this diminution is not due to division. Kölliker finds them to present at last the appearance of the so-called sympathetic fibres; becoming pale, with a simple contour line disposed to form varicosities. Thus, though no neurilemma could be distinguished, the dark border shows that they are not free axis-cylinders, or non-medullated fibres, such as are seen in other terminations of nerves.

Fig. 269.

Divisions of the nerve-fibres in muscle. (Magnified 350 diameters.) A. Double division from the omohyoid muscle in man. *a*, *a*, *a*. Neurilemma. B. Division of a nerve from a facial muscle of the rabbit into three apparently pointed twigs. (*Kolliker.*)

It is also certain that divisions of the nerve-fibres occur in the muscles of man, though they are rare and detected with difficulty. (Fig. 269.) Their relation to the loops is still to be made out.

In many of the small muscles the extent of space to which the nerve-fibres are distributed is very limited. In a portion of the superior belly of the omo-hyoid, three inches long, the portion to which the nerves are distributed is not more than five to six lines in length. The trunk of the nerve enters in the middle of the transverse axis of the muscle, and divides into two primary branches, one passing to the right and the other to the left border of the muscle. Each of these gives off numerous anastomosing branches of all sizes, thus supplying the entire thickness of the muscle from the most superficial to the deepest layers. The rest of the muscle usually presents a complete deficiency of nerves. The same conditions obtain in the lower belly of the omo-hyoid, in the sterno-hyoid, sterno-thyroid, subcruralis, &c. It appears to be true in respect to the larger muscles also, that their separate portions are in connection with the nervous plexus, only at a point of limited extent. Whether the muscular fibres are in contact with nerves only at a single point when the former are of the greatest length (as in the sartorius, latissimus dorsi, &c.), is not yet decided.

Nerves are also found accompanying the *vessels* of muscles (nervi vasorum); but these present no peculiarities. They are composed of the finest fibres alone, and are distributed to the arteries and veins (seldom to the smallest), but not to the capillaries. How they terminate is still unknown. Some fibres also from the muscular plexus before described, occasionally join those of the vessels.

The larger *tendons* contain the vascular nerves only, and the smaller none at all. The fasciæ and the sheaths of the tendons, as well as the synovial capsules (bursæ mucosæ), contain none.

Peculiarities in the Lower Animals.—In the *invertebrata*, the nerve-fibres are known to terminate in the muscles by free extremities, which, after expanding, are inserted into the muscular fibres. The divisions are sometimes trifid. In them, also, every muscular fibre appears to have a nerve-fibre distributed to it; and often accompanying it for a considerable distance, and forming loops or spirals around it. In the *amphibia* the divisions are multiple (Fig. 270), and even eight-fold. (*Wagner.*) The ultimate filaments are pale and have a simple contour line. They do not penetrate the muscular fibre, but are merely closely applied to it, either obliquely, transversely, or longitudinally, for some distance; becoming in all

cases attenuated to a sharp point, frequently as fine as a fibre of the white fibrous tissue. (*Kölliker.*)

In the *mylo-hyoideus* muscle of the frog, Reichert found 160 to 180 fibres, and the nervous trunks to contain "7 to 10 fibres, ultimately forming from 290 to 340 filaments by continual division, or more than one for each muscular fibre."

Fig. 270.

Divisions of nerve-fibres in a small twig from the cutaneous thoracic muscle of the frog. *a.* Bifurcation. *b.* Threefold division.—Magnified 350 diameters. (*Kölliker.*)

Accessory Organs of the Muscles.

Under this head are included:—

1. The muscular envelops, or fasciæ.
2. Ligaments of the tendons.
3. Tendinous sheaths and the synovial sacs (bursæ mucosæ).
4. Fibro-cartilages and sesamoid bones.

1. *The Muscular Envelops* (*Fasciæ*), *&c.*

The fasciæ are fibrous membranes surrounding single muscles (sartorius, &c.), or entire groups of muscles, with their tendons. The deep fasciæ of the extremities (femoral, brachial, and ante-brachial aponeuroses, &c.), are illustrations. These also give insertions to muscles, and thus become tendons (tensor vaginæ femoris), or

give origin to them, and thus become aponeuroses; *e. g.* the interosseous membrane of the forearm and leg. They are also, in certain parts, thickened into ligaments (as on the dorsal aspect of the carpus), to retain the tendons in place. In all these cases, they present the character and structure of tendons and ligaments.

In some instances, however, the distinct muscular sheaths are formed of areolar tissue, and are hence extensible, and allow of a considerable amount of motion of the muscle within them; *e. g.* sterno-cleido-mastoideus, and other muscles manifesting a considerable amount of motion under the skin.

2. *The Ligaments of the Tendons.*

These retain the tendons in their place in certain parts; *e. g.* the dorsal and palmar ligaments of the carpus, which retain the extensors and the flexors of the fingers—and the corresponding ligament of the foot.

Small bundles of white fibrous tissue also strengthen the tendinous sheaths next to be described, as minuter ligaments.

All the ligaments, mentioned under this head, present the structure and character of those in relation with joints (p. 278), and contain fewer vessels than the tendons.

3. *The Tendinous Sheaths and Synovial Sacs.*

The sheaths of the tendons (as of the flexors and extensors of the fingers and toes) are usually described as closed serous membranes, of which one portion invests the tendon and the other lines the special canal in which it glides to and fro. Kölliker, however, finds that no membrane at all exists on the greater part of the surfaces hitherto supposed to be covered by it. Fimbriated processes are, however, found projecting here and there into the cavity containing the synovial fluid, and from which the latter is doubtless secreted. These processes are very vascular, like those of the synovial capsules of the joints (p. 345).

The *bursæ mucosæ*, or synovial capsules of the muscles, invest the opposed surfaces of muscles and bones, as under the psoas, iliacus, deltoid, gluteus maximus, &c. (p. 195). These also appear in the form of closed sacs, but are usually not everywhere constituted of a serous membrane, any more than the preceding tendinous sheaths. In both, the epithelium is almost never complete; and both are, therefore, to be classed with the synovial capsules of the joints.

Cartilage-cells are, however, to be found in the textures entering into the synovial capsules of the muscles; though genuine cartilage has not yet been found on the opposed and gliding surfaces of muscles and bone, except in case of the cuboid bone.

4. *Fibro-Cartilages and Sesamoid Bones.*

A layer of fibro-cartilage is found covering the grooves on bones, in which tendons glide (tibialis posticus, peroneus brevis, &c.); and frequently the tendon also is thickened by a layer of the same tissue on the surface which glides on the bone. But on the cuboid bone, under the tendon of the peroneus longus, is a layer of true cartilage, $\frac{1}{36}$ to $\frac{1}{24}$ of an inch thick.

Fibro-cartilages also exist normally in the flexor tendons of the fingers and toes; their free surface presenting towards the articulations. If they become ossified, they are called *sesamoid bones* (*e. g.* in flexor tendon of thumb, great toe, in ligamentum patellæ, &c.). These are covered by a thin layer of cartilage next the joint, and blend with the tendinous structure on the other side.

Physical Properties of the Muscles.

In the muscular tissue of man (*i. e.* including the perimysia, &c.), there are usually 72.56 to 74.45 per cent. of water, and 25.55 to 27.44 per cent. of solid residue. The analysis of the latter has been given on page 396, where the highest extreme of the water is put at 80 per cent.

The bright red color of the muscles has already been accounted for (p. 397).

The muscles are capable of being stretched—even the tendons are not totally inextensible in their natural condition (p. 409)—and also manifest a certain degree of the physical property of *elasticity.* This is exemplified by the return to their former condition of the muscles of the abdomen, after being stretched during pregnancy and by dropsical accumulations. The muscles even of a dead animal still return thus after being stretched, though they do not altogether resume their original form, and therefore are more readily torn. Still, such a slender muscle as the gracilis may support a weight of eighty pounds after death, without breaking. Kölliker thinks the rigor mortis is produced by an increase of elasticity, and is not a vital phenomenon, as the author of the present work has

considered it (p. 405). The elasticity doubtless inheres in part in the myolemmata of the muscles, since they resemble elastic tissue.

Physiological Remarks.

The use of the muscles depends on the vital property inherent in the muscular fibres—*contractility*, or spontaneous shortening—producing motion in the parts (bones especially) with which they are connected. The tendons and aponeuroses only serve to transmit the motor force generated in the muscular fibres. Hence the tendons of the flexors and extensors of the fingers and toes are elongated, in order to remove the belly of the muscle to a distance, and secure beauty of proportion in the limbs. During contraction, the fibres shorten in a rectilinear direction, but do not undergo any considerable condensation. Their tenacity is, however, much increased; so that the tendon gives way rather than the belly of the muscle, if rupture occurs from violent contraction—as in the tendo-Achillis, &c. Ordinarily, only a part of the fibres in a muscle contract at the same time (p. 402). Thus the full strength of a muscle is seldom exerted, and usually only under the highest excitement—as in mania, &c.

It has been stated that the muscles ordinarily contract in consequence of a stimulus communicated to them by the nerves (p. 402). Of the nature and precise mode of their action, we, however, know nothing; though it may be inferred that, in the *vertebrata*, the nervous influence acts from a certain distance, since the nerve-fibres touch the muscular fibres only at a few points, and never penetrate into their interior (p. 416).

The *intrinsic* contractile force of a muscle depends not on its length, but on the number and size of its fibres, or its transverse sectional area. The *extent* of motion, however, at the point of insertion, depends, *cæteris paribus*, on the length of the fibres, and can never exceed three-fourths to five-sixths of the length of the belly of the muscle, since no individual fibre shortens more than in this proportion (p. 402). When, however, the fibres are short, a compensation in respect to the amount of motion of the part to be moved may be secured by having the insertion of the muscle nearer to the extremity of the bone to be moved by it—*e. g.* the semi-membranosus, as compared with the semi-tendinosus. The *available* or *effective* force of a muscle depends much on its relations to the part into which it is inserted. Most of the muscles are inserted in such

a way as to act at a mechanical disadvantage (*i. e.* so as to act at first nearly parallel to the surface of bones they move, or near the extremities of the latter). Thus their effective is much less than their intrinsic force. *E. g.* the intrinsic force of the deltoid has been estimated at 1,000 pounds; while its available force is perhaps not more than 50 pounds. As a compensation for this loss of force, greater velocity and extent of motion of the part are secured with a given amount of shortening of the muscular fibres.

The *tonicity* of the muscles has been spoken of on page 403.

The muscles possess *sensibility*, though of a peculiar kind; they becoming painful and sensitive to pressure after long-continued action, and after being affected with cramps or spasms; while scarcely any sensation is excited by punctures, burns, and incisions into their substance. They also possess a delicate sense of feeling for their own state of contraction, and estimate very minute variations in the force with which they act. It is this kind of sensibility (called the muscular sense) which enables us to judge of the weight of objects. The sense of fatigue is also peculiar to the muscles. It has already been shown that the muscles contain but few sensitive nerve-fibres (p. 415)—enough, probably, to give merely the slight impressions normally characterizing the muscles in ordinary circumstances; while they may also give rise to pain, even, when compressed for a time during their contraction.

The muscles, during their contraction, elicit a peculiar *sound*, of a silvery character, and which somewhat resembles the rumbling of distant carriage-wheels. This is probably produced by modifications in the circulation, as well as by the changes occurring in the fibres themselves.

Heat is also developed by muscles during contraction, as has already been explained (p. 402); oxygen being absorbed and carbonic acid being given off by them at the same time.

Development of the Muscles.

The manner in which the striated muscular fibres are developed, has already been explained (p. 399). The muscles are not evident as distinct organs in the human fœtus before the end of the second month, and can then be seen only under the microscope; and the tendons cannot be distinguished from the other portions. In the tenth to the twelfth week they are more distinct; and the tendons

may also be distinguished, as somewhat clearer but still transparent streaks.

In the fourth month, both the muscular tissue and the tendons are more distinct, the former being, on the trunk, of a light reddish color. At birth, the muscular fibres are still softer and paler, and the tendons more vascular and less white than they subsequently become.

The elementary parts of the tendons are never formed earlier than those of the muscular portion. Indeed, they cannot be recognized as fasciculi of the white fibrous tissue till about the fourth month, though the muscular fibres are quite distinct at the eighth to the ninth week. Being $\frac{1}{10000}$ to $\frac{1}{7500}$ of an inch in diameter at the fourth month, the fasciculi (at first containing no distinct fibres) become $\frac{1}{6000}$ to $\frac{1}{4800}$ of an inch in diameter at birth. At this time, also, their fibres are distinct, and the fine elastic fibres are developed between the fasciculi from special fusiform formative cells. Fig. 271 shows the wavy appearance of the fasciculi at birth, and also the elongated nuclei lying upon and among them, from which the elastic fibres are probably developed. (See also Figs. 261–2.)

Fig. 271.

From the tendo-Achillis of a new-born child, magnified 250 diameters; and treated with acetic acid, to show the formation of the fine elastic fibres. (*Kölliker.*)

In the adult, the fasciculi of the tendons are $\frac{1}{2000}$ to $\frac{1}{1500}$ of an inch in diameter. Their relative size, therefore, in the fœtus at four months, the new-born child, and the adult, are as 1 : 1.8 : 6; so that the growth of the tendons, after birth at least, seems due to the increased thickness and elongation of their fasciculi; while their number also is constantly increased during fœtal life.

Pathological States of the Muscles and their Accessories.

The pathological states of the striated muscular tissue have already been specified (p. 406); of which hypertrophy, atrophy, paralysis, fatty degeneration, and softening are the most important.

The most common pathological state of the tendons and aponeuroses is *atrophy*, consequent on the same condition of the muscular fibres, and disease of the muscle. The tendons also become shortened in case of talipes (club-foot) and other deformities; since changes in the relations of the bones have brought the points of in-

sertion of the tendons abnormally near to the belly of the muscle. Hence the propriety of dividing the tendons, and bringing the bones into their normal relations, in such cases; after which, the former assume the normal length by a new formation of collagenous tissue between the divided extremities.

The vaginal sheaths of the tendons, especially of the extensors of the fingers, are liable to dilatations and accumulations of the synovial fluid, forming protrusions called *ganglia*. The most common seat of the ganglion is on the dorsum of the wrist.

The synovial sacs of the muscular system (bursæ mucosæ) are also liable to inflammation, and consequent distension, from the fluid they contain. The affection usually termed "housemaid's knee" is an inflammation of a synovial sac, not connected with the muscular system, but existing between the patella and the skin covering it.

CHAPTER X.

NERVOUS TISSUE, AND THE STRUCTURE OF THE NERVOUS SYSTEM.

SECTION I.

THE NERVOUS TISSUE.

Two forms of the nervous tissue are to be described:—

I. The fibrous or tubular nerve-tissue.
II. The vesicular or cellular (nerve-cells).

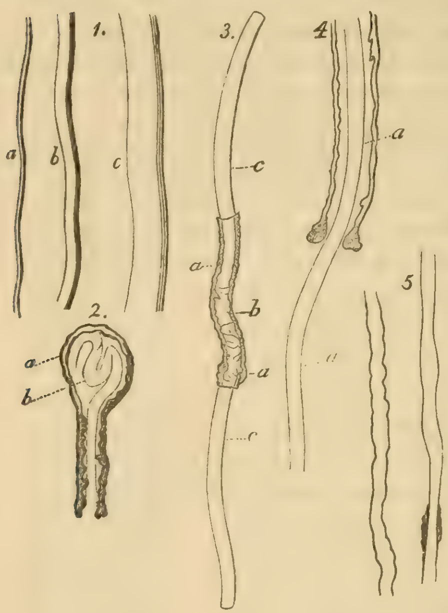
I. Fibrous or Tubular Nerve-Tissue.

This form of nerve-tissue is termed tubular, because, when developed in the highest degree, it presents the form of tubes inclosing a fibre. In other cases, however, the tube is wanting, and then the term "fibrous" is more appropriate. The latter are far more minute than the former; and hence these two forms have been called by Kölliker the coarse and the fine nerve-fibres. (Fig. 272.) There is also a medium size, averaging about the $\frac{1}{4000}$ of an inch in diameter.

The *coarsest* nerve-fibres are even $\frac{1}{1200}$ of an inch in diameter; while the finest have only $\frac{1}{20}$ this diameter, or $\frac{1}{24000}$ of an inch.

The *length* of the nerve-fibres also varies extremely; since they have one extremity in the part where they are distributed, while the other enters the encephalon or spinal cord (to constitute their white or fibrous portions), or terminates in ganglia.

Fig. 272.



Nerve-fibres. 1. From the dog and rabbit, in their natural condition: *a*, fine; *b*, of medium thickness; *c*, coarse fibre from the peripheral nerves. 2. From the frog, with the addition of serum: *a*, drop of the contents expressed; *b*, axis-fibre within the drop continued into the tube. 3. From the spinal cord of man; recent, with serum added: *a*, neurilemma; *b*, medulla with double contour; *c*, axis-fibre. 4. Double contoured fibre from the fourth ventricle in man; the axis-fibre (*a*) projecting, and visible within the fibre. 5. Two isolated axis-fibres from the cord, one undulated, the other of unequal thickness, with some medullary substance attached to it.—Magnified 350 diameters. (*Kölliker.*)

1. *The Coarse* (*large*) *Nerve-Fibres.*

It is, of course, impossible to draw any precise line between the coarse and the medium nerve-fibres, since all grades of size are found between their extremes of $\frac{1}{1200}$ of an inch as the diameter of the coarsest, and $\frac{1}{24000}$ as that of the finest fibres. Nor is it of any importance that the intermediate should be distinguished as such; since they appear to present no peculiarity in structure or function. Kölliker, however, mentions as coarse fibres those above $\frac{1}{3000}$ of an inch; as medium those from $\frac{1}{6000}$ to $\frac{1}{3000}$ of an inch; and as fine those less than $\frac{1}{6000}$ of an inch.

All the nerve-fibres, when examined in their recent state, and by transmitted light, appear perfectly transparent, and with simple dark contours. By reflected light they appear opaline, like fat, and, in large quantities together, white; but generally they do not appear to be composed of different constituent parts.

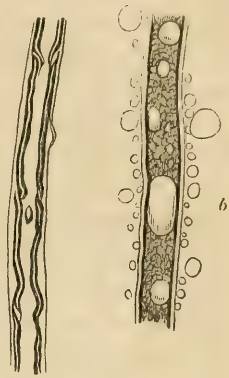
All the coarse fibres may, however, be shown to consist of (Fig. 273, and Fig. 272, 3, 4)—

A. The envelop, or neurilemma.

B. Its contents, the *neurine;* consisting of the medulla and the axis-fibre. (Fig. 274.)

A. The *neurilemma*[1] is formed of simple membrane, and resembles elastic tissue, but is less soluble in alkalies. Histologically, it very much resembles the myolemma of striated muscular fibre, and has nuclei upon its inner surface (p. 393, 1). It has not yet been demonstrated in the finest fibres. Moreover, in case of the largest tubes it disappears both at its distal extremity, where it is distributed, and also in the brain or spinal cord, on tracing it to its origin. Sometimes, also, it is wanting even in the coarser fibres through a considerable extent of their terminal portions.

Fig. 273.



Nerve-tubes of the common eel. *a.* In water. The delicate line on its exterior indicates the neurilemma; the dark double-edged inner one is the white substance of Schwann (medulla), slightly wrinkled. *b.* The same in ether. Several oil-globules have coalesced in the interior, and others have accumulated around the exterior of the tube. The white substance has in part disappeared. (Magnified 300 diameters.)

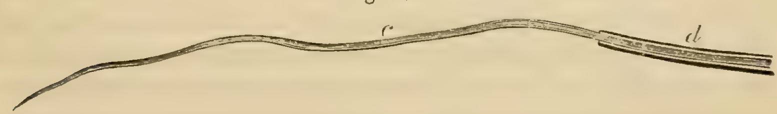
B. The *contents* of the neurilemma are a homogeneous substance during life, according to certain observers; and the appearances described by Rosenthal and Remak are regarded by such as due to *post-mortem* changes. The conclusions of Kölliker on this question are adopted here.

Two entirely distinct substances are contained in the nerve-tube; a difference in color, however, and density, being apparent only after death. These are:—

1. The axis-fibre.
2. The nerve-medulla, or pulp.

1. The *axis-fibre* (*Kölliker*), primitive band (*Remak*), or axis-cylinder (*Rosenthal*), is a pale, soft, cylindrical or slightly flattened, but

Fig. 274.



An axis-fibre (*c*) is seen prolonged some way beyond the broken edge of its neurilemma and the white substance, or medulla (*d*).

[1] From νεῦρον, nerve, and λέμμα, a coat or sheath. This term is used to correspond with the myolemma of muscular tissue; while the perineurium and the perimysium also correspond.

elastic fibre (Fig. 274), in the *centre* of the tube, and usually occupying about *one-third* of its diameter. It is generally homogeneous, though rarely faintly striated or finely granular; is usually throughout of uniform size, *solid*, and resembles coagulated albumen. It generally pursues a straight course, but may be curved or slightly undulating (never varicose), with an irregular border. Chemical reagents also show that it contains not a trace of fat, but is an albuminous compound; though it is not identical with the fibrine of the blood, nor the peculiar element of muscular tissue (musculine). Analogically with the latter immediate principle, it may be termed *nervine.*

The axis-fibre is found in all, even the very finest, nerve-tubes; and in the latter, it only can always be satisfactorily demonstrated. Its size varies with that of the nerve-fibre itself. During life, however, it cannot be distinguished from the medulla which surrounds it.

In the acoustic nerve of the sturgeon, Czermàk has demonstrated the existence of bifurcating axis-fibres in dividing nerve-fibres.

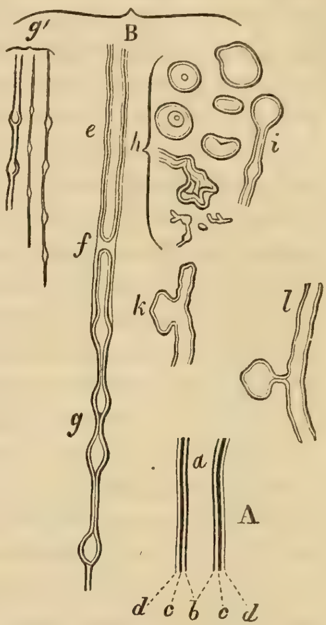
2. The nerve-*medulla*, or pulp, is a thick, viscid *fluid*, like thick oil of turpentine, mostly composed of fatty matter, and filling all the space between the axis-fibre and the inner surface of the neurilemma. Consequently it occupies the two remaining, or *external*, *thirds* of the diameter of the tube. In other words, it is itself a viscid, fluid, hollow cylinder, completely inclosing and isolating the solid axis-fibre, which is placed within it. Hence its designation, also, as the *medullary sheath.* It has also been called the "white substance of Schwann."

The entirely different chemical reactions of the medulla and the axis-fibre, would seem to demonstrate their distinct existence and function; though the microscope does not distinguish them during life. It is the medulla that gives the dark border to nerve-tubes under the microscope; and such are therefore termed *medullated* or *dark-bordered* tubes.

Although the axis-fibre exists in every nerve-fibre, many are met with which have no medulla—*non-medullated* fibres. These consist of the neurilemma, the axis-fibre, and an intervening fluid, sometimes identical in appearance with the latter, and sometimes similar but more clear. These *non*-medullated fibres are also found to occur in continuation of the medullated, both when they communicate with the nerve-cells in the encephalon and spinal cord, and also at the peripheral extremities of the fibres.

The medulla is rapidly and invariably altered by the application of cold water, of most acids, &c. This change consists principally in a coagulation of it, sometimes occurring from without inwards, and involving the entire thickness, or only its outermost layer. In the latter case, the nerve-fibres of double contour lines are produced; in the former, the contents become apparently wholly grumous or opaque. The neurilemma gives the single contour line. Sometimes, also, the medulla accumulates into larger masses in places, and thus the frequently described varicose appearance of the nerve-fibres is produced. (Figs. 275 and 273.) In this change the neurilemma participates; but in all those mentioned, the axis-fibre takes no part. By pressure, the medulla may be made to assume all possible forms.

Fig. 275.



A. Diagram of a tubular fibre of a spinal nerve. *a*. Axis-fibre. *b*. Inner border of medulla. *c, c*. Its outer border. *d, d*. Neurilemma.—B. Tubular fibres. *e*. In a natural state, showing the parts as in *a*. *f*. The medulla and axis-cylinder interrupted by pressure, while the neurilemma remains. *g*. The same, with varicosities. *h*. Various appearance of the medulla and axis-fibre, forced out of the neurilemma by pressure. *i*. Broken end of an axis-fibre with the medulla closed over it. *k*. Lateral bulging of medulla and axis-fibre from pressure. *l*. The same, more complete. *g'*. Varicose fibres, of various sizes, from the cerebellum. (Magnified 320 diameters.)

2. *The Fine Nerve-Fibres.*

The finest nerve-fibres (Fig. 298, 3) are only $\frac{1}{24000}$ of an inch in diameter; and in these neither neurilemma nor medulla can be demonstrated, only the axis-fibre being apparently present. Most of them are, however, $\frac{1}{15000}$ to $\frac{1}{8000}$ of an inch; but these also have no proper medulla—*i. e.* are *non*-medullated. But they contain between the axis-fibre and the neurilemma a substance sometimes resembling the axis-fibre of other nerves, and sometimes more clear. These are often called pale nerve-fibres, as they have only a single contour line. In the nervous centres, also, they frequently present a varicose appearance. (Fig. 275, *g'*.)

It has already been seen, however, that a nerve-fibre may be medullated, coarse, and have a neurilemma, in one part of its course,

while it is non-medullated, pale, or even consists of the axis-fibre alone, in another part. The division into coarse and fine fibres is therefore more important, doubtless, in a histological than in a physiological point of view. The axis-fibre alone is a constant structure.

Pale or non-medullated fibres naturally occur in the following situations: 1. Those of the Pacchionian bodies; 2. The nucleated pale fibres in the terminations of the olfactory nerves; 3. The perfectly transparent non-nucleated fibres in the cornea; 4. The pale processes of the nerve-cells in the central organs and ganglia. It will appear that all the nerve-fibres of the embryo are in the condition of the pale fibres now under consideration. We, however, find them in different stages of development in the adult. In the olfactory nerve they remain altogether in the embryonic stage, the contents being much less consistent than an axis-fibre. In the Pacchionian bodies their contents in all respects represent an axis-fibre; and the processes of the nerve-cells often exactly resemble an axis-fibre, though they are frequently of a softer consistence, corresponding with the contents of the nerve-cell.—In the *invertebrata*, only the pale nerve-fibres are found.

The preceding are the only forms of fibres found in the cerebro-spinal nervous system.

But is there not still another variety of nerve-fibres (gray fibres) peculiar to the sympathetic or ganglionic nerves?

So far as any peculiar appearance under the microscope is concerned, the reply may be decidedly in the negative; though Bidder and Volkmann maintained that these fibres are smaller than those in the cerebro-spinal nerves, and also in other respects different.

The fact is, the cerebro spinal nerves contain dark-bordered tubes of all sizes, from the finest to the largest; those derived from the sensitive roots of the spinal nerves being generally finer than those from the motor roots. But the branches of the sympathetic also contain the same varieties of nerve-fibres, the only perceptible difference being that the *proportion of the finer tubes*, $\frac{1}{10000}$ to $\frac{1}{6000}$ of an inch in diameter, *is greater in the sympathetic nerves.* Some of these fine fibres are also known to originate in the ganglia of the sympathetic, but in a manner similar to the origin of the fine fibres of the cerebro-spinal nerves in the cord and the encephalon. We also find fine fibres, precisely like the so-called sympathetic fibres, constituting the distal termination of the coarsest nerve-fibres; and that all the coarsest double-bordered nerve-fibres are, at a particular

period of their development, precisely in the condition of these fibres of the sympathetic. Finally, it is even true that the *same fibre* in the adult is often seen to assume all possible varieties of size in different portions of its course.

There are, therefore, no nerve-fibres peculiar to the sympathetic nerves; there being only the fine and the large fibres already described as existing in the cerebro-spinal system.

How, then, may we dispose of still other fibres found more especially in the peripheral branches of the ganglionic (sympathetic) nerves—the "gelatinous fibres," or "fibres of Remak?" These, when isolated, present the aspect of flat, pale fibres, $\frac{1}{8000}$ to $\frac{1}{4800}$ of an inch wide, and $\frac{1}{20000}$ of an inch thick, of an indistinctly striated, granular, or more homogeneous substance. In these, acetic acid shows elongated or fusiform nuclei, averaging about $\frac{1}{2400}$ of an inch in length, and $\frac{1}{4800}$ of an inch in width. (Fig. 276.) They are found in great abundance in the nerves of the impregnated uterus (*Remak*), sometimes amounting to from three to ten times the number of the dark-bordered true nerve-fibres.

Fig. 276.

Gelatinous fibres (fibres of Remak) from the solar plexus; treated with acetic acid to exhibit their cell-nuclei.—(Magnified 320 diameters.)

With Valentin, Kölliker, Bidder, and Volkmann, we regard the fibres just described merely as a form of elastic tissue, or nuclear fibres. For, 1*st*, they appear to arise from the *wall* of the nerve-cells of the sympathetic ganglia; 2*dly*, they also exist in the finest twigs of the spinal nerves, but, being absent in the trunks, must be otherwise than nerve-fibres; 3*dly*, their quantity always diminishes towards the finest ramifications, which could not be the case were they true nerve-fibres. This question cannot, however, be settled in young animals; though in them a nucleated fibre is not to be regarded as a nerve-fibre, unless it can be traced into a dark-bordered nerve-fibre, or to a process of a nerve-cell.

Finally, the fibres of Remak occur also in the ganglia on the main sympathetic trunk; but they do not extend much beyond them, and therefore few are contained in the trunk of the nerve itself.

Distribution of the Nerve-Fibres.

The nerve-fibres constitute the principal part of all the nerves, both cerebro-spinal and ganglionic. They also constitute most of

the white (fibrous) portion of the encephalon and the spinal cord; while they also sometimes form even one-half of the gray substance of these two organs and of the ganglia.

It has already been shown that there are at least eight or nine times as many coarse as fine fibres in muscles (p. 415); while the fine fibres greatly predominate in the ganglionic nerves.

Chemical Composition of the Nerve-Fibres.

It appears that the neurilemma and the axis-fibre very much resemble elastic tissue, and are albuminous compounds; while the medulla is rather a fatty compound. It is not, however, to be supposed that either of these three has a chemical composition precisely identical with that of any other tissue whatever. The nerve-tissue has vital properties which are *sui generis*, and doubtless its chemical composition is peculiar. When the immediate principle peculiar to this tissue is identified, it may, from analogy, be called *nervine* (p. 426). A quantitative analysis of the nerve-fibres occurring to form masses, will be given in connection with the fibrous substance of the brain.

The vessels of the nerve-fibres will also be described further on.

Functions of the Nerve-Fibres.

It is very certain that the nerve-fibres, in all cases, merely minister to the central parts of the nervous system; being merely[1] the media by which impressions are transmitted to and from the latter.

From the statement of Volkmann (p. 415), we must infer that many at least of the coarser fibres, if not all, are employed in transmitting impulses to the muscles, and are therefore *motor* nerve-fibres. On the other hand, the fine fibres are not motor, since in muscles they are sent to the vessels especially (p. 416). They also abound in the ganglionic nerves. The inference, therefore, is, that the fine fibres must include both the sensory and the ganglionic, and both of which are *afferent*—*i. e.* they conduct impressions to the centres and ganglia; while the coarse fibres are *efferent*. Still, we must not assert that a motor fibre is coarser throughout its entire extent, since they sometimes become very fine at their distal extremity.

In regard to the office of each of the three component parts of

[1] In the performance of this function, however, "the whole extent of the fibre between the point stimulated and its peripheral and central connection is the seat of change" (*Todd and Bowman*, p. 235.)

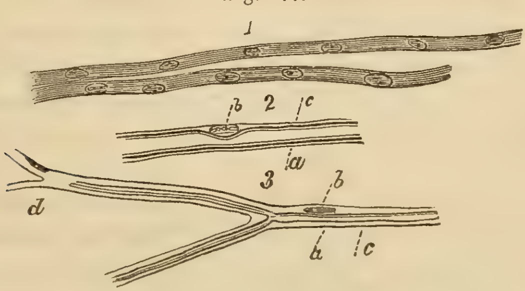
the nerve-fibres, we would submit that the neurilemma is originally for the development of the contained parts; the medulla protects and isolates the axis-fibre; while the latter is endowed with the peculiar vital property of the fibre, whether it be efferent or afferent. Thus the motor fibres, being most exposed to undergo pressure among the muscular fibres while contracting, need a thicker medulla, and are therefore coarser. The fibres of the ganglionic nerves are at the other extreme in this respect; since they are mostly distributed to internal parts and organs, and at the same time follow vessels more especially. It also occurs, that a thick medulla at the distal extremity of a sensory fibre would of course interfere with a prompt impressibility of the axis-fibre, though it might become medullated while lying in the nerve-trunks. Evidently, also, the protection of a medulla is not required after the fibres enter the substance of the encephalon and spinal cord; and here the fibres are non-medullated.

For the present, therefore, we are not perhaps allowed to assume more than that a fibre which is thickly medullated throughout its entire course, is very probably a motor fibre. But some of the finer fibres *may* also be motor. The finest fibres are not peculiar to the ganglionic nerves; and if they actually manifest a peculiar function (i. e. *as the great sympathetic*), that function is probably manifested by the spinal nerves also, in proportion to the fine fibres they contain.

Development of the Nerve-Fibres.

The peripheral portions of the nerve-fibres are developed independently of the central portions; but in such a way that the lat-

Fig. 277.

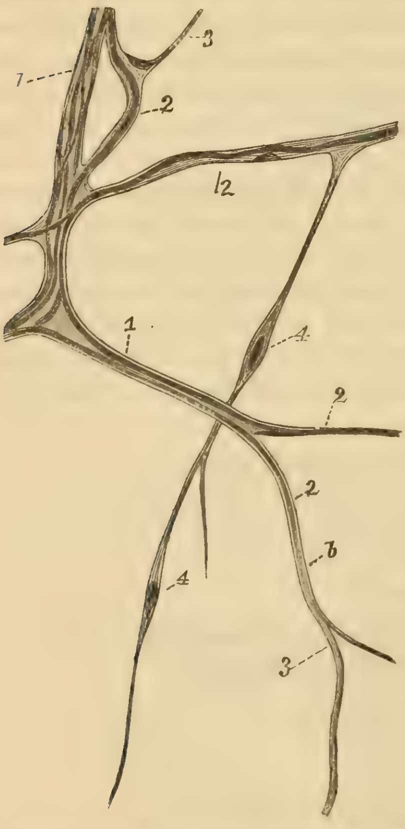


1. Two nerve-fibres from the ischiatic nerve of a sixteen weeks' embryo. 2. Nerve-tubes from a newly littered rabbit. *a*. Neurilemma. *b*. Nucleus. *c*. Medullary sheath. 3. Nerve-fibre from the tail of the tadpole (*a*, *b*, *c*), as before; at *d*, the fibre retains its embryonic character; the dark bordered fibre shows a division. (*Kolliker*.)

ter precede the former. The development of the peripheral *extremities* of the nerve-fibres is also peculiar, and requires a distinct consideration.

1. The *nerve-fibres* in the nerve-trunks, except their peripheral terminations, are developed in their positions, from primordial, fusiform, nucleated cells, conjoined into pale, flattened, nucleated tubules, $\frac{1}{12000}$ to $\frac{1}{4000}$ of an inch broad. (Fig. 277.) In this state they are gray, or dull white; but in the embryo at the 4th to the 5th month, they assume a white color, and the medulla continues to be more and more developed in them, and thus they become dark-bordered fibres.

Fig. 278.



Nerves from the tail of a tadpole. 1. Embryonic nerve-fibres in which more than one dark-bordered tube has been developed. 2. Similar fibres containing but one tube, which in one fibre ceases at (*b*). 3. Embryonic pale fibres; 4, fusiform cells connected together, and with a complete nerve-fibre.—Magnified 350 diameters. (*Kölliker.*)

Thus the axis-fibre appears to be developed from the central portion of the contents of the original tubule, while the external portions undergo a sort of fatty metamorphosis into the medulla.

2. The development of the *peripheral terminations* of the nerve-fibres, has been investigated satisfactorily only in the tail of the tadpole. The pale nucleated tubules described under the preceding head, here and there anastomose, and terminate in free fibrils of the finest kind, $\frac{1}{60000}$ to $\frac{1}{30000}$ of an inch in diameter.—These are evidently formed from the coalescence of fusiform or stellate cells; and continue to be pushed further by offsets towards

the periphery, and finally form a very fine terminal plexus, with anastomoses and free ends. (Fig. 278.) Next, the fibres gradually enlarge to from two to four times their original diameter, and dark bordered fine fibres are gradually developed in them in the peripheral direction. Sometimes two to four dark-bordered tubules are developed within the same embryonic fibre, in the tadpole; a fact not yet established in regard to the higher animals.

3. The development of the nerve-fibres in the *central organs* has not been thoroughly investigated. Tubules begin to form, however, in the white substance of the fœtal brain at the end of the 2d month, by the coalescence of cells. In the 4th month, nuclei are still occasionally to be seen in the now wider fibres, though the latter do not become dark-colored before the middle period of fœtal life; and in the white portion of the cord sooner than in that of the brain.

The fibres in the ganglia are developed subsequently to those of the nerve-trunks, and apparently in the manner just described.

The *growth* of the nerve-fibres is apparently secured, after the 4th month of embryonic life, solely by the enlargement of the already existing elements. No new fibres are found after this period. According to Harting, the size of the fibres in the median nerve in the human fœtus at 4 months, the new-born child, and the adult, is as 3.4, 10.4, and 166.

When nerve-fibres are cut across, they readily unite; and portions, 8 to 12 lines long, may be entirely regenerated, when removed from the peripheral nerves. Incised wounds of the spinal cord unite also. (*Brown-Séquard.*)

Pathological States and New Formations of the Nerve-Fibres.

1. The nerve-fibres are readily *destroyed* by extravasation of blood, tumors, softening, fibroid growths, &c.; in which case the medulla breaks up into larger or smaller masses, while the axis-fibre disappears. Continued pressure sometimes leads to a complete interruption of continuity of the fibres at the point compressed.

2. In *atrophied* nerves the fibres are thinner, easily broken up, and sometimes the medulla is converted into minute fatty molecules.

3. It is not known that *hypertrophy* of the nerve-fibres ever occurs.

4. In case a divided nerve does not unite (as necessarily after amputation), the fibres usually become yellowish, soft, lacerable, and

no longer present any trace of a double contour, the medulla being coagulated.

5. What is called *neuroma* is decided by Wedl to be, sometimes at least, a cancerous deposit in the continuity of a nerve.

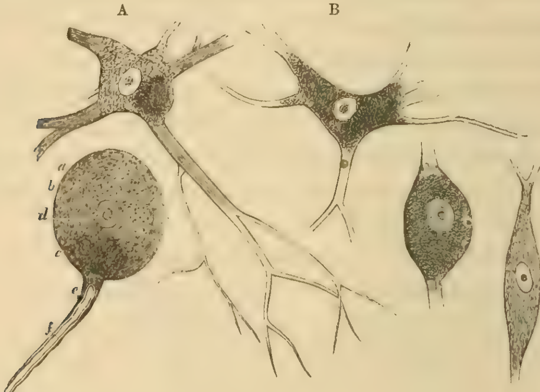
6. A *new formation* of fine nerve-fibres was noticed by Virchow in pleuritic and peritoneal adhesions.

II. Cellular (*vesicular*) Nerve-Tissue, or Nerve-Cells.

The nerve-cells (nerve-corpuscles, *Valentin*) vary extremely in their size; occurring, like the nerve-fibres, as large, small, and intermediate. The extremes are $\frac{1}{6000}$, and $\frac{1}{200}$ of an inch. The nuclei are from $\frac{1}{8000}$ to $\frac{1}{6000}$ of an inch, and the nucleoli $\frac{1}{24000}$ to $\frac{1}{4000}$ of an inch in diameter.

Many varieties of *form*, are also presented by the nerve-cells. (Figs. 279 and 280). The spherical form (apolar cells) occurs more

Fig. 279.



Various forms of nerve-cells. A, B. Large stellate cells with their prolongations; from the anterior horn of the gray matter of the spinal cord. C. Nerve-cell with its connected fibre; from the anastomosis of the facial and auditory nerves at the meatus auditorius internus of the ox. *a*. Cell-wall. *b*. Cell-contents. *c*. Pigment. *d*. Nucleus. *e*. Prolongation forming the neurilemma, *f*, of the fibre. D Nerve-cell from the substantia ferruginea of man. E. Smaller cell from the spinal cord. (Magnified 350 diameters.)

abundantly in the ganglia; but the original form of most nerve-cells is modified by prolongations—poles, or pale processes. Of these there may be from 1 to 5, or even 8; hence the cells are termed uni-, bi-, tri-, or multi-polar. These processes are also frequently branched. (Fig. 280.) There are, however, no cells with branched processes in the ganglia; but only those having 1 to 4 pale processes, and which are continuous with dark-bordered nerve-fibres.

The *cell-membrane* may be demonstrated easily in the cells of the ganglia, but with great difficulty in those of the central organs, and not at all in the smallest cells of the latter. No membrane can be detected in the processes of the central cells generally.

The *contents* of the nerve-cells are a soft, tenacious, elastic, substance, consisting of two elements, besides the nucleus; (1), a clear, light-yellowish, or colorless, homogeneous substance, an albuminous compound very much resembling the axis-fibres, and on which the physical properties of the contents depend; and (2), minute granules of different kinds suspended in the former. These are sometimes larger and yellowish, brown, or blackish; in which case the cells are colored (as forming the gray matter of the nervous centres); while in the colorless nerve-cells they are minute and pale, uniform, and roundish in form. They consist, in great part, of fat.

The *nucleus* lies in the midst of the contents just mentioned; usually as a very clear spherical vesicle with distinct walls, transparent contents, and one, and rarely several, opaque nucleoli, occasionally exhibiting a cavity.

Distribution of the Nerve-Cells.

The nerve-cells occur in great numbers in the gray substance of the encephalon and spinal cord, in the ganglia, and occasionally also in the trunks and peripheral expansions of the nerves; as in the retina, cochlear nerve, &c.

Chemical Composition and Physical Properties of the Nerve-Cells.

The chemical composition of the gray portion of the brain (made up, in great part, of the cells in question), will be given further on in this chapter.

If isolated nerve-cells are compressed, they become much flattened, but resume their original form after the pressure is removed. Their processes also are very elastic.

An abundance of blood is distributed to the nerve-cells. The vessels will be described in the second part of this chapter.

Functions of the Nerve-Cells.

Since the nerve-cells constitute the principal element in the gray matter of the centres, and of the ganglia, and this presides over the higher functions of the nervous system, while its other portions are

merely a conducting apparatus (p. 430); it must be inferred that the cells are the source of motor impulses on the one hand, and the recipients of sensory impressions on the other.

It has been seen that the largest nerve-fibres are certainly mostly motor, and the finest sensory and ganglionic. We also find the largest nerve-cells in situations whence motor effects proceed: as in the anterior horns of the spinal cord, among the fibres of the anterior roots of the spinal nerves; in the medulla oblongata, at the points of origin of the motor cerebral nerves; and in the cortical substance of the cerebellum, pons Varolii, and crura cerebri. On the other hand, the smallest cells are found in the sensitive and sympathetic regions—as the posterior horns of the spinal cord, the corpora restiformia, and quadrigemina; and in the sympathetic ganglia. Still, there is no constant relation between the size of the cells and their function, whether motor, sensory, or sympathetic; since in the optic thalami and in the ganglia of the cerebro-spinal nerves, and even of the sympathetic, both sorts of fibres arise, from large cells in one place, and from small ones in another. There are, however, more small cells in the sympathetic ganglia.

But it must be remembered that many of the cells in the cerebrum and the cord are probably neither motor, sympathetic, nor sensory. Such are those which are not in direct connection, through

Fig. 280.

a. A large nerve-cell with diverging and branching processes, some of which (b) are seen to pass off into extremely minute filaments. These bear a very close resemblance to the axis-cylinder of a tubular fibre. c. Small nerve-cells. f. Small nerve-fibres, some being varicose.

their processes, with the nerve-fibres. Of these there are two kinds: 1*st*, apolar cells, existing in the sympathetic ganglia, and in some situations in the brain (Fig. 289); 2*dly*, multipolar cells (Fig. 280),

which are not prolonged into nerve-fibres. It is not easy to specify the function of the former; but since the processes of the latter apparently fulfil the functions of nerves, it is probable that they bring different regions of the central organs into mutual connection. Cells of this kind exist in the spinal cord and the brain everywhere, in large amount, but not in the ganglia.

The cells in the gray matter of the brain, which is regarded as the seat of the mental manifestations, exhibit no peculiarities by our present means of research.

While, therefore, we may regard cells connected with nerve-fibres as being either motor or afferent, the functions of the apolar, and the multipolar not thus connected, must be established by future investigations.

Development of the Nerve-Cells.

The nerve-cells are merely transformed primordial cells; some simply enlarging, while others throw out a varying number of processes, and some of them are connected with nerve-fibres.

Many nerve-cells also appear at a subsequent period to increase by division, from the fact that two nuclei sometimes occur in the nerve-cells of young animals.

Valentin thinks he observed *regeneration* of nerve-cells in the superior cervical ganglia of the rabbit. Gluge also maintains that the gray matter of the brain is reproduced after being removed.

Pathological States and New Formations of the Nerve-Cells.

The deposit of pigment-granules becomes excessive in the cells of the brain in old persons. Fatty deposition also occurs in them—a fatty degeneration.

The *ganglia* become *atrophied* in old persons; in which case the ganglion-cells are less numerous, and contain more pigment. Atrophy of the abdominal ganglia also occurs as a sequel of typhus. (*Raciborski.*)

A *new formation* of gray nerve-cells sometimes occurs on the walls of the cerebral ventricles. (*Virchow.*)

SECTION II.

STRUCTURE OF THE NERVOUS SYSTEM.

The nervous system consists of—

I. The nerves proper, and their ganglia.
II. The nervous centres.

I. Structure of the Nerves.

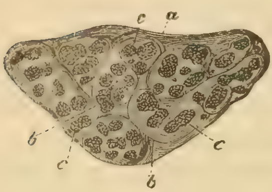
The nerves contain the following histological elements:—

1. Nerve-fibres.
2. Areolar tissue.
3. Bloodvessels.

1. The nerve-fibres have been sufficiently described (pp. 423–9).

2. The areolar tissue is insinuated between the individual fibres in the nerve-trunks, and also invests the whole nerve externally, and is therefore termed the *perineurium*.[1] Fig. 281 shows a section of the ischiatic nerve of the calf, and the areolar tissue between its component nerve-fibres; the latter being first collected into the primary fasciculi, and these into the secondary, as has been shown in respect to the fibres of muscle and of tendon. The finest subdivisions (internal perineurium) of the perineurium, lying between the fibres are in the form of a homogeneous membrane, with nuclei $\frac{1}{4000}$ of an inch in diameter, and which may be regarded as embryonic collagenous tissue (p. 276). The elastic fibres are not seldom entwined around whole fasciculi.

Fig. 281.



Transverse section of the ischiatic nerve of the calf. *a* External perineurium. *b*, *c*. Internal perineurium investing the separate fasciculi of nerve-fibres of which the nerve-trunk is made up.—Magnified 15 diameters. (*Kölliker.*)

3. The *bloodvessels* of the nerves are not very numerous. They extend principally in a longitudinal direction, and form a loose plexus of minute capillaries of $\frac{1}{6000}$ to $\frac{1}{3000}$ of an inch, with elongated interstices. This invests the fasciculi, and penetrates them, but never surrounds individual nerve-fibres.

The nerves, in respect to their origin, are of three kinds, and will be described in the following order:—

1. The spinal nerves.
2. The ganglionic nerves.
3. The encephalic nerves.

[1] From περί, around, and νεῦρον, a nerve.

1. *The Spinal Nerves.*

The thirty-one pairs of nerves connected with the spinal cord rise from two roots, anterior and posterior, or motor and sensory. (Fig. 282.) Sometimes, however, the first nerve has only an anterior root, and the last a posterior only.

Fig. 282.

The two roots of a dorsal spinal nerve, and its union with the sympathetic. *c, c.* Anterior fissure of the spinal cord. *a.* Anterior root. *p.* Posterior, with its ganglion. *a'.* Anterior *branch.* *p'.* Posterior *branch.* *s.* Sympathetic. *e.* Its double junction with the anterior branch of the spinal nerve by a white and a gray filament.

1. The *roots* of the spinal nerves are inclosed in a delicate perineurium derived from the *pia mater*, $\frac{1}{6000}$ of an inch thick, and sending internal septa among the individual nerve-fibres, which are coarse in the motor root. Anastomoses between the roots frequently occur, and far most so between the posterior roots.

The two roots converging, separately perforate the arachnoid and dura mater, and receive a firmer investment from the latter; then proceeding further, the posterior root forms its ganglion; after which the two roots unite to form the common spinal nerve-trunk.

2. The *ganglion* on the posterior root is formed as follows: Nerve-cells (*ganglion-cells*) are developed among, but principally externally to, the nerve-fibres, each giving off one, two, or several nerve-fibres (*ganglion-fibres*), which proceed in company with the original sensitive fibres of the posterior root, and merely pass among the ganglion-cells, and reunite after traversing the ganglion. The root, however, becomes somewhat increased in size from the addition of the ganglion-fibres. (Fig. 283.)

The *ganglion-cells* have a distinct membrane, are mostly rounded, elongated, or pyriform, and a little flattened, averaging $\frac{1}{600}$ to $\frac{1}{400}$

Fig. 283.

A lumbar ganglion of a young dog, treated with soda. *S.* Sensitive root. *M.* Motor root. *R. a.* Anterior branch of the spinal nerve. *R. p.* Posterior branch. In both, their derivation from both roots is manifest. *G.* Ganglion, with the cells and ganglion-fibres, *g*, which assist in strengthening the sensitive roots, traversing the ganglion. (Magnified 45 diameters.)

of an inch. Their contents are finely granular throughout, and frequently exhibit near the nucleus an accumulation of yellow or yellowish-brown larger pigment-granules, which increases in old age. The nuclei average $\frac{1}{2000}$, and the nucleoli $\frac{1}{9000}$ of an inch. The cells are more abundant on the surface of the ganglion, between the perineurium and the original sensitive fibres; but they also occupy the interstices between these fibres. They are apparently retained in their place by offsets from the perineurium, and which form a special nucleated capsule around them, called their *external sheath*. (Fig. 284.) "Fibres of Remak" are also found among the elements of the ganglia (p. 429).

By far the greatest number of the *ganglion-cells* give off pale processes $\frac{1}{8000}$ to $\frac{1}{5000}$ of an inch in diameter. These are continued into dark-bordered and double-contoured nerve-fibres (the *ganglion-fibres*). (Fig. 285, A.)

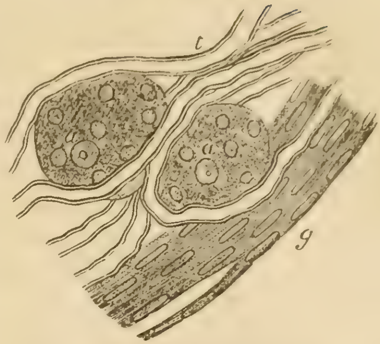
Possibly apolar ganglion-cells also exist, but this is not certain;[1] and if there be any bipolar cells, both their ganglion-fibres are be-

[1] Apolar cells are frequently met with in the *ganglia aberrantia* of Hyrtl; *i. e.* the inconstant larger or smaller collections of cells on the posterior roots of some of the larger spinal nerves.

lieved to extend in the peripheral direction.

3. The *ganglion-fibres* thus arising, which frequently arch round, or embrace the cells with several circular turns, are at first fine, or $\frac{1}{8000}$ to $\frac{1}{5000}$ of an inch; but increase up to $\frac{1}{4000}$, $\frac{1}{3000}$, and even to $\frac{1}{2000}$ of an inch, while still within the ganglion, thus becoming thick fibres. The special sheaths of the pale processes are, however, continued over the fibre only till it leaves the ganglion, when the common perineurium takes their place.

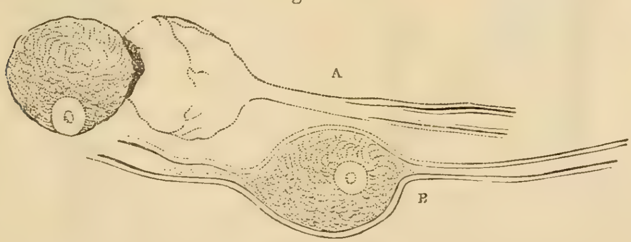
Fig. 284.



From the Gasserian ganglion of an adult. *a*, *a*. Ganglion cells with their nucleus, nucleated capsule, and pigment. *t*. Tubular fibres running among the cells in contact with their capsule. *g*. Gelatinous (Remak's) fibres also in contact with the ganglion-cells. (Magnified 320 diameters.)

It is clear that the subdivisions of the trunks of the spinal nerves formed as already explained, will contain motor, sensory, and gan-

Fig. 285.



Connection between nerve-fibres and nerve-cells; from the roots of a spinal nerve of the ray. A. A nerve-cell escaped by pressure from the capsule formed around it, by the dilated sheath of the nerve-tubule; it shows also the gradual disappearance of the outer portion of the substance of the nerves as it comes into relation with the cells. B. A nerve-cell inclosed within a dilated portion of the neurilemma of a nerve; part of the granular material of the cell is continuous with the axis-fibre of the nerve in the course of which it is inserted.

glionic nerve-fibres. The coarse fibres are finally sent to the muscles, and the finer are given off in the cutaneous nerves, and those of other sensitive parts. The ultimate distribution of the ganglionic fibres has not been anatomically settled. They are, however, probably mostly given off in the vascular nerves of the extremities, glands, and skin.

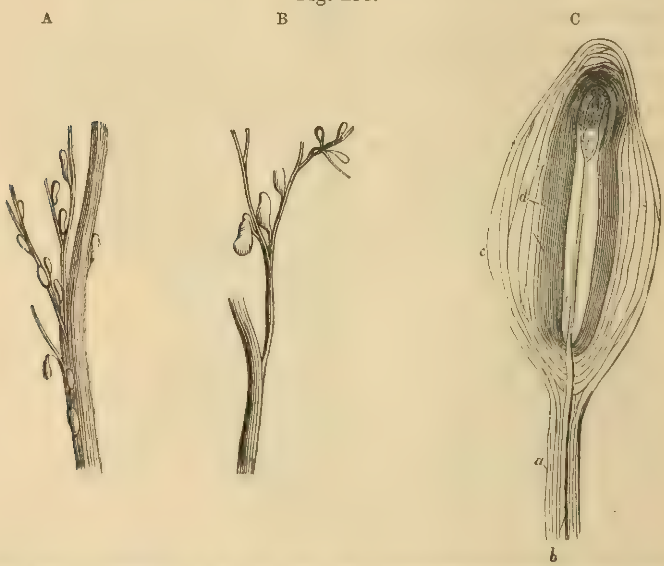
The proportion of the coarse to the fine fibres in the main trunks of the spinal nerves, is as 10 to 11; while in the muscular nerves it

is as 10 to from 1 to 3.3. (*Bidder and Volkmann.*) The nerves of bone contain in their trunks $\frac{1}{3}$ of coarse, and $\frac{2}{3}$ of fine fibres; while those of the articulations, tendons, and membranes, exhibit a great preponderance of fine fibres. (*Kölliker.*)

4. The manner in which the motor nerve-fibres terminate (by divisions, &c.), has already been described (p. 416). The terminations of the sensory fibres in loops, divisions, and free terminations, will be described in the chapter on the skin. (Chap. XI.)

A peculiar form of termination of the spinal nerves, is however to be noticed here; viz., that in the *Pacinian bodies*.[1] These organs

Fig. 286.



A. Nerve from the finger, natural size; showing the Pacinian corpuscles. B. Ditto, magnified 2 diameters; showing their different size and shape. C. Single corpuscle, highly magnified, showing *a*, its peduncle, *b*, its contained nerve-fibre; *c*, outer layers, and *d*, inner layers of the capsule; *e*, nerve-fibre become pale in its passage through the interior of the corpuscle; *f*, its subdivision and termination.

are of an elliptical or pyriform shape, of a whitish transparent color, with white streaks internally, and are from $\frac{1}{24}$ to $\frac{1}{6}$ of an inch in diameter. They are constantly found on the cutaneous nerves of the palm of the hand, and the sole of the foot, in the subcutaneous areolar tissue, and most numerously on the fingers and toes, particularly on the third phalanx. There are about 600 in the hand, and not quite so many in the foot. (Fig. 286.) They are always

[1] From Pacini, who discovered them in 1840.

found, also, in the sympathetic plexus in front of, and close to, the abdominal aorta, behind the peritoneum, especially near the pancreas; frequently in the mesentery close to the intestine; and *occasionally* on the internal pudic nerve, on the glans penis, the bulb of the urethra, the intercostal nerves, sacral plexus, cutaneous nerves of the arm and forearm, the dorsum of the hand and foot, and the cutaneous nerves of the neck.

The Pacinian bodies consist of twenty to sixty concentric layers of connective (areolar) tissue; the external being separated by wider, and the internal by narrower interspaces, containing a clear serous moisture, and which is collected in larger quantity in an elongated central cavity bounded by the innermost lamella (Fig. 287). A rounded peduncle formed from the continuation of its lamellæ, and connected with a nervous twig, incloses a dark nerve-fibre, $\frac{1}{2000}$ of an inch or more in diameter, and conducts it into the central cavity of the Pacinian body. Here it becomes $\frac{1}{2000}$ of an inch wide, and $\frac{1}{3000}$ of an inch thick, pale, non-medullated, almost like an axis-fibre, and terminates in the distal part of the cavity in a free, slightly granular tubercle, frequently with a bifid or a trifid extremity.

Fig. 287.

Pacinian corpuscle, from the mesentery of a cat; showing the general construction of these bodies. The stalk and body, the outer and inner system of capsules, with the central cavity, are seen. *a.* Arterial twig ending in capillaries which form loops in some of the intercapsular spaces, and one penetrates to the central capsule. *b.* The fibrous tissue of the stalk prolonged from the perineurium. *n.* Nerve-tube advancing to the central capsule, there losing its medulla, and stretching along the axis to the opposite end, where it is fixed by a tubercular enlargement.

The *function* of these bodies is still entirely unknown.

5. The *anastomoses* of the branches of the spinal nerves, constituting the several plexuses, present no histological peculiarities, and may be studied in the works on descriptive anatomy.

2. *The Ganglionic Nerves.*

These are usually included under the designation of the "sympathetic nerve," or "nerves of organic life." They are to be regarded rather as an appendage to the spinal nerves, and are hence next to be described.

The sympathetic nerve consists of a whitish trunk with a series of ganglia (Fig. 282, *s*) upon it; into which branches pass from the spinal nerves (the rami communicantes.) In the chest and abdomen, these ganglia and the main nerve are situated on each side of the spinal column.

We have to consider:—

A. The connecting branches.
B. The ganglia, and their fibres.

A. The *rami communicantes* rise from the trunks of the spinal nerves immediately after they are formed by the junction of the anterior and posterior roots. They contain both the coarse and the fine nerve-fibres, but always a preponderance of the latter; of which a portion may be derived from the spinal ganglia. They may thus be regarded as the *roots* of the sympathetic. Possibly they are derived in some small degree from the sympathetic itself also; the fibres from the latter source, however, entering the main trunk with the rest.

Having entered the trunk of the sympathetic, the communicating branches run both upwards and downwards in it, towards its cephalic and pelvic extremities. Finally, they doubtless go off to be distributed in its peripheral branches; since all the latter frequently contain the same dark-bordered thicker fibres.

B. The *ganglia* of the sympathetic have essentially the same structure as the spinal ganglia. They consist (1) of perforating nerve-fibres, proceeding from one part of the trunk to the other, besides those of the rami communicantes; (2,) of numerous ganglion-cells, and (3) of ganglion-fibres originating from the last. (Fig. 288.)

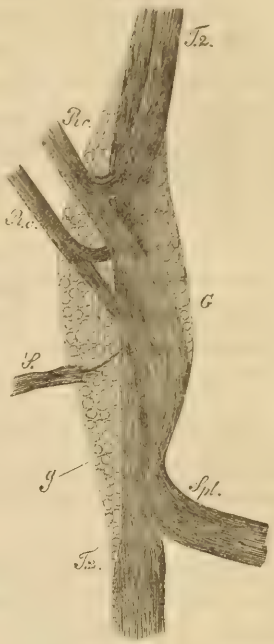
1. The perforating fibres require no special description.

2. The *ganglion-cells* precisely resemble those in the spinal ganglia (Fig. 284), except that they are, on an average, smaller; being $\frac{1}{5000}$ to $\frac{1}{1200}$ of an inch in diameter, with less and paler pigment, or even none at all; and usually pretty uniformly rounded. Cells,

however, exist in the spinal ganglia as small as any found here. On the other hand, some of these measure even $\frac{1}{400}$ of an inch. They are mostly unipolar, and very rarely bipolar. Apolar cells are also more abundant than in the spinal ganglia. (Fig. 289.)

3. The *ganglion-fibres* are of the finest kind, $\frac{1}{10000}$ to $\frac{1}{6000}$ of an inch in diameter. They are dark-bordered, but pale. They constitute a large proportion of the sympathetic trunk, and its branches, but are in no respect peculiar to it, as has been shown (p. 429). The existence of these fibres does not confer a special function on the sympathetic nerve, and which does not exist elsewhere; though they may manifest a peculiar function *wherever found*, whether in the sympathetic or the spinal nerves.

Fig. 288.



Sixth thoracic ganglion on the left side of the sympathetic nerve of the rabbit, seen from behind, and treated with soda. (Magnified 40 diameters.) *T*2. Trunk of the sympathetic. *Rc*, *Rc*. Rami communicantes, each dividing into two branches. *Spl*. Splanchnic nerve. *S*. Twigs of the ganglion with two stronger fibres and finer filaments probably going to vessels. *G*. Nerve-cells and ganglion-fibres joining the main trunk. *g*. Ganglion-cells. (*Kölliker*.)

The "fibres of Remak" which have already been described, also enter into the structure of the peripheral branches of the sympathetic nerves; and sometimes constitute three-fourths or even nine-tenths of the branch (p. 429).

A great number of *ganglia* also occur on the peripheral branches of the sympathetic, some of them of merely microscopic dimensions. They have a structure like that before described, and the ganglion-cells give off new fibres, so that the emergent branches always contain an increase of them. In these also many of the cells are apolar.

How are the fibres of the sympathetic finally distributed?

1. The fibres terminate by division in some cases; *e. g.* the nerves of the spleen, in the Pacinian bodies of the mesentery, in the nerves temporarily existing in the uterus of the rodentia, and those of the dura mater on the meningeal arteries, &c. 2. There are free terminations of the fibres; as in the Pacinian bodies, and the mesen-

Fig. 289.

Apolar nerve-cells from the cardiac ganglia of the frog; one within the origin of a nerve-tube.—Magnified 350 diameters. (*Kolliker.*)

teric vessels of the frog. 3. The thicker fibres become the finest kind, and ultimately non-medullated embryonic fibres, in all probability. But nothing precise is yet known respecting their terminations in the heart, lungs, stomach, intestine, kidneys, spleen, liver, uterus, &c.

The many *plexuses* of the great sympathetic, and which affect a relationship to the aorta and its abdominal subdivisions, present no histological peculiarities.

3. *The Encephalic Nerves.*

The twelve pairs of nerves rising from the encephalon correspond (except the first, second, and eighth pairs) so closely with the spinal nerves in most respects, that only a brief description of them is here required.

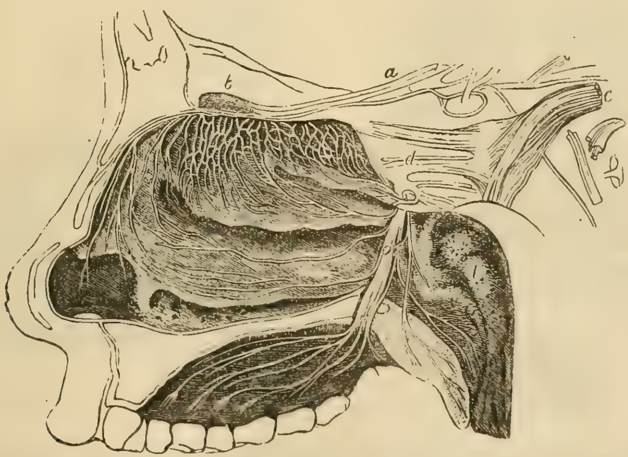
All these nerves, except the fifth pair (trigeminus), ninth (glosso-pharyngeal), and tenth pair (pneumogastric), and perhaps the eleventh (spinal accessory)—rise from a single root instead of two; and are, therefore, exclusively motor or exclusively sensory. The *fifth* pair is, however, histologically and physiologically a spinal nerve; and for the description of its ganglion (the Gasserian), and its final distribution, we refer to the spinal nerves. Several ganglia are, however, placed upon it (submaxillary, &c.), as upon the sympathetic; and they present the same structure also as the latter, except that they contain a considerable number of larger nerve-cells. The *ninth* pair (glosso-pharyngeal), though endowed with motor properties, has no fibres which do not pass through the one or the other of its ganglia. Its ultimate ramifications in the tympanic cavity and in the tongue, contain small ganglia. The *tenth* pair (pneumo-gastric) has all its roots enter the jugular ganglion in man; while in several lower animals (dog, cat, rabbit, &c.), it has a primary fasciculus not connected with the ganglion. The latter presents no peculiarity, except that the nerve-cells occasionally measure only $\frac{1}{1333}$ of an inch, though there are many as large as $\frac{1}{400}$ of an inch. The ultimate distribution of this nerve exhibits a constant separation of thicker from more slender fibres; so that the branches to the œsophagus, heart, and stomach are composed almost entirely of fine fibres; while in those going to the lungs, and in

the superior laryngeal nerves, the finer are to the thick only as 2 to 1. On the other hand, in the inferior laryngeal nerves and the pharyngeal branches, the thick fibres are to the fine as 6, or even 10, to 1. All these fine fibres are not, however, derived from the great sympathetic; but mostly from the ganglion-cells on the original roots of this nerve. (*Kölliker.*) The *eleventh* pair (accessory of Willis) is perhaps also in part sensitive; but has no cells, and, so far as is known, presents nothing peculiar.

The *motor* encephalic nerves are the third pair (oculo-motores); fourth pair (patheticus); sixth pair (motor externus); seventh pair (facial), and twelfth pair (hypoglossal). All these present the same conditions as the anterior roots of the spinal nerves, except that all of them anastomose with sensitive nerves, and thus carry sensitive as well as motor fibres to the muscles. A ganglion is also found in the facial nerve (intumescentia ganglioformis); and also on the third pair in the ox, according to Rosenthal and Purkinje. This occurrence of new cells in motor nerves is not yet explained.

Terminal loops within the trunks of the encephalic nerves had been noticed by Gerber, and since by Valentin. Their significa-

Fig. 290.



Outer wall of the nasal fossa with the three spongy bones and meatus; the nerves being shown as they would appear through the membrane if it were transparent. *a* Olfactory process. *b*. Olfactory bulb (represented rather too short), resting on the cribriform plate. Below is seen the plexiform arrangement of the olfactory filaments on the upper and middle spongy bones. *c*. Fifth nerve within the cranium with its Gasserian ganglion. *d*. Its superior maxillary division, sending branches to Meckel's ganglion, and through that to the three spongy bones, where they anastomose with the olfactory filaments, and with (*s*) branches of the nasal division of the ophthalmic nerve. *o*. Posterior palatine twigs from Meckel's ganglion supplying the soft and hard palate. *t*. Orifice of the Eustachian tube. From Sœmmering; two-thirds diameter.

tion is unknown; as is also that of the nervous filaments seen by Remak and Bochdalek, coming out from, and again re-entering the brain.

The three remaining encephalic nerves are nerves of *special sensation;* viz., the first pair (olfactory), the second pair (optic nerves), and the eighth pair (acoustic).

1. The *first pair* is the nerve of smell. The portion of this nerve lying on the cribriform plate of the ethmoid, is called the *bulb;* and the rest, extending from this to the cerebrum, the *tract.* Both these are made up of the common dark-bordered nerve-fibres.

The *branches*, on the other hand, which are given off from the bulb into the upper portions of the nasal passage (Fig. 290), contain no white medullated fibres at all; but are constituted of pale, slightly granular, flattened fibres (Fig. 291, 6), $\frac{1}{6000}$ to $\frac{1}{4000}$ of an inch wide, with elongated nuclei retained closely in connection by common sheaths of connective tissue, which are thicker in the branches to the septum. (Fig. 292.) In the bulb, however, nerve-

Fig. 291.

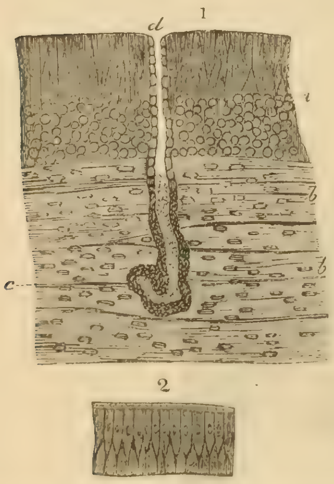


Fig. 292.

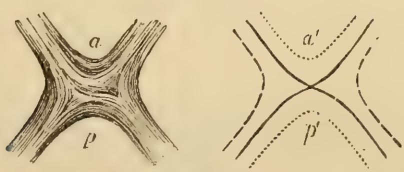
Fig. 291. From the nasal mucous membrane of the sheep. 1. From the *regio olfactoria*, transverse section of the mucous membrane; *a*, epithelium without cilia; *b*, olfactory nerves, with a dividing pale nucleated fasciculus; *c*, one of "Bowman's glands;" *d*, its orifice. 2. Ciliated epithelium of the Schneiderian membrane.—Magnified 350 diameters. (*Kölliker.*)

Fig. 292. Nerves of the septum of the nose. *a*. Olfactory bulb resting on the cribriform plate, below which its branches may be traced on the septum about half way down. Behind, the naso-palatine nerve from Meckel's ganglion is seen descending to the naso-palatine canal. In front, the nasal twig of the ophthalmic nerve descends towards the tip of the nose, dividing into two principal branches. *p*. Roof of the mouth. *e*. Orifice of the Eustachian tube.—Magnified one-half diameter. (*Arnold.*)

cells of $\frac{1}{15000}$ to $\frac{1}{4000}$ of an inch, many with branched fibres, are found among the nerve-fibres. The latter very closely resemble the embryonic nerve-elements, and are probably derived from the olfactory bulb, and not from the cerebrum itself. It is doubtful how they terminate. The surface over which they are distributed, called the "olfactory region," extends only $\frac{3}{4}$ to 1 inch below the *lamina cribrosa* of the ethmoid bone (Fig. 290); and on this surface alone the epithelium of the mucous membrane is not ciliated. (Fig. 291.)

2. The *second pair* of encephalic nerves is the nerve of *vision.* The optic nerve has its *tract* composed of dark-bordered fibres $\frac{1}{6000}$ of an inch in diameter. In the *chiasma*, some of the fibres pass to the retina of the same side, and some to that of the other side; while others still, form a loop in the posterior part of the *chiasma*, and thus connect the origins of these nerves; and a fourth set are looped in a similar manner anteriorly to connect the two retinæ. (Fig. 293.) The fibres are much disposed to become varicose, but

Fig. 293.

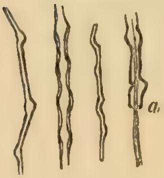


Course of fibres in the optic chiasma, as exhibited by tearing off the superficial bundles from a specimen hardened in spirits. *a*. Anterior fibres commissural between the two retinæ. *p*. Posterior fibres commissural between the thalami. *a'*, *p'*. Diagram of the preceding.

the nerve-cells among them, mentioned by Hassall, have not been found by Kölliker. They form polygonal bundles $\frac{1}{250}$ to $\frac{1}{187}$ of an inch in diameter, surrounded by a perineurium of the usual kind, and which is replaced by the sclerotica on their reaching the eyeball. The fibres undergo no change till after entering within the sclerotica and forming the slight elevation (*colliculus nervi optici*), on the retina opposite its point of entrance. But from that point onwards, the fibres become perfectly clear, yellowish or grayish, and transparent, like the finest fibres in the central organs, and mostly from $\frac{1}{60000}$ to $\frac{1}{15000}$ of an inch, though some are $\frac{1}{12000}$ to $\frac{1}{6000}$ of an inch. They, however, have no nuclei in their course, and are inclined to varicosities like the minutest fibres of the cerebrum. (*Kölliker.*) (Figs. 294 and 298, 3.)

These fibres radiate on all sides from the *colliculus* before mentioned, and constitute a continuous membraniform expansion extending as far as the *ora serrata* of the retina; presenting no considerable interruption, except at the situation of the *macula lutea*, where they are almost wholly wanting. In this expansion the fibres are associated into compressed bundles, $\frac{1}{1200}$ to $\frac{1}{1000}$ of an inch wide, either anastomosing with each other at very acute angles, or lying parallel for considerable distances. It is $\frac{1}{333}$ of an inch thick at the bottom of the eye, and, gradually decreasing, only $\frac{1}{8000}$ near the *ora serrata*, or anterior termination. How these fibres terminate, is still unknown. (Fig. 295, 1.)

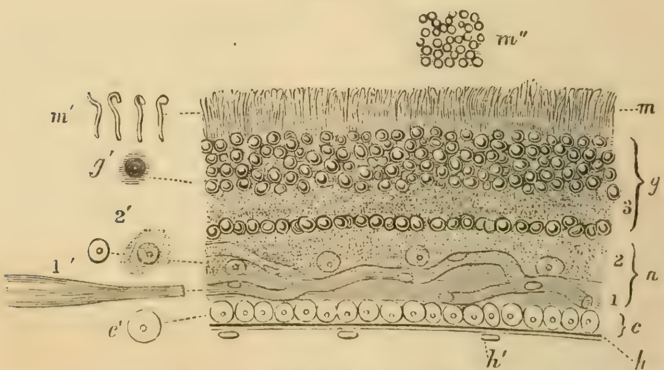
Fig. 294.



Fragments of nerve-tubules from the human optic nerve, of various sizes, and varicose. At *a* the axis-fibre projects beyond the medulla at a broken extremity. (Magnified 320 diameters.)

The expansion of the optic nerve just described by no means constitutes the *retina*, however. The latter consists of five distinct layers, of which this expansion constitutes one. These are from within outwards. (Fig. 295.)

Fig. 295.

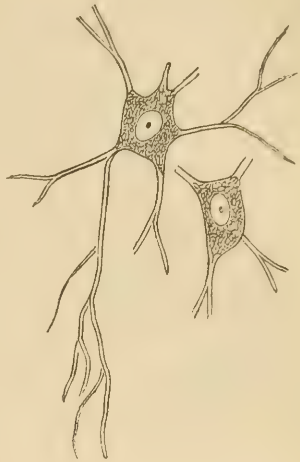


Vertical section of human retina and hyaloid membrane. *h′*. Nuclei on inner surface of latter. *h*. Limitary membrane. *c*. Layer of transparent (epithelial?) cells. *c′*. Separate cell, enlarged by action of water. *n*. Gray nervous layer, with its capillaries. 1. Fibrous layer (optic nerve). 2. Gray vesicular layer. 1′. Shred of fibrous lamina, detached. 2′. Cell and nucleus, detached. *g*. Granular layer. 3. Light lamina, frequently seen. *g′*. Detached nucleated particle of granular layer. *m*. Jacobson's membrane. *m′*. Its bacilli, detached. *m″*. Its outer surface. (Magnified 320 diameters.)

1. The limitary membrane.
2. The expansion of the optic nerve.
3. The layer of gray nerve-substance.
4. The granular layer.
5. The bacillar layer (rods and cones).

1. The limitary membrane, *h*, is merely a simple membrane, $\frac{1}{24000}$ of an inch thick. Its inner surface presents towards the hyaloid membrane of the vitreous body. On its outer surface Todd and Bowman found a layer of epithelial (?) cells (*c*), but which Kölliker has not seen.

Fig. 296.

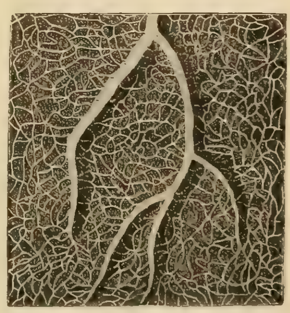


Nerve-cells with processes, from the retina of the ox.—Magnified 350 diameters. (*Kölliker.*)

2. The next layer—the expansion of the optic nerve (1)—has just been described (p. 450).

3. The layer of *gray cerebral substance* (2) penetrates between the fibres of the optic nerve, but is quite well defined on its outer surface. It is composed of a finely granular matrix, exactly resembling that in the gray substance on the surface of the cerebrum and cerebellum; containing numerous scattered nerve-cells. Some of the latter, in the outer half of this layer, are small ($\frac{1}{6000}$ to $\frac{1}{2000}$ of an inch); others, in the inner portion, $\frac{1}{2000}$ to $\frac{1}{750}$ of an inch. They have from two to six, or more, pale branched processes (Fig. 296), like those of the central nerve-cells; these processes being at first $\frac{1}{6000}$ of an inch in diameter, but diminishing in repeated divisions to scarcely $\frac{1}{30000}$ of an inch. They appear always to be given off towards the exterior, but curve so as to ramify in the gray layer itself. Its entire thickness varies at points from $\frac{1}{6000}$ to $\frac{1}{2400}$ of an inch. The distribution of its capillaries is shown by Fig. 297.

Fig. 297.



Distribution of capillaries in the vascular (gray) layer of the retina.

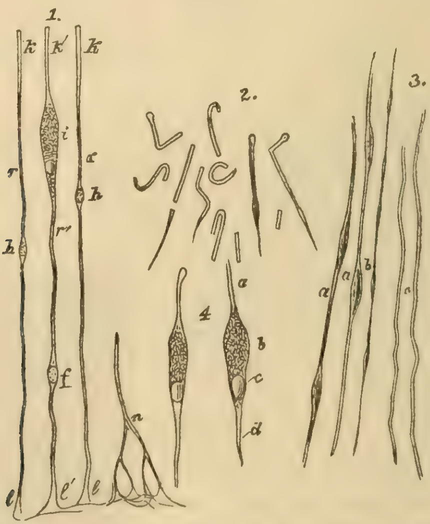
4. *The granular layer* (Fig. 295, *g*). In man, the granules are disposed throughout most of the retina in two layers—an internal, thinner ($\frac{1}{2000}$ to $\frac{1}{1500}$ of an inch), and an external, thicker ($\frac{1}{923}$ to $\frac{1}{750}$ of an inch). Between these is a clear, finely granular, and somewhat vertically striated layer (3), $\frac{1}{2000}$ to $\frac{1}{1500}$ of an inch thick. Towards the *ora serrata*, however, the two form a single structure of not more than

$\frac{1}{8000}$ of an inch thick. The granular bodies themselves are round or oval, and $\frac{1}{6000}$ to $\frac{1}{3000}$ of an inch in diameter, with very fine filaments extending from both sides, of $\frac{1}{60000}$ to $\frac{1}{40000}$ of an inch.

5. The external layer of the retina is the *bacillar layer*, or Jacobson's membrane (m). Its structure is very remarkable, presenting two elements—the rods (bacilli) and the cones (coni)—blended together in a single layer, $\frac{1}{333}$ of an inch thick at the bottom of the eye, $\frac{1}{500}$ more anteriorly, and quite in front not more than $\frac{1}{800}$ of an inch.

The *rods* are cylindrical, slender, elongated corpuscles, consisting of two portions, the larger external end, or proper rod, and the internal, or *filament.* The former is a cylinder $\frac{1}{1600}$ to $\frac{1}{800}$ of an inch long, and $\frac{1}{15000}$ of an inch broad, and truncated at the outer end; while the inner is produced into a short point, $\frac{1}{5000}$ to $\frac{1}{4000}$ of an inch long from the inner extremity of the rod; is of uniform width, and extends through the inner half of the bacillar layer. The substance of the rods is clear and homogeneous, with a faint, glistening, fatty aspect, and is very soft, flexible, and fragile. They

Fig. 298.

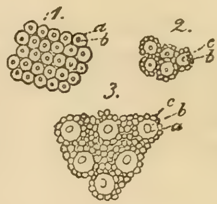


Retinal elements of man. 1. "Rods" and radiating fibres: k, proper "rod;" r, prolongation of its pointed inner extremity; h, "granule" (cell) of the outer granular layer; l, enlarged extremity of the radiating fibres, proceeding from them to the surface of the optic layer; k', "rod" seated on a "cone" (i); r', fibre proceeding from the latter, connected with the "granule" (f) of the inner granular layer, and the terminal enlargement (l) on the inner surface of the retina; n, one of the fibrous bundles in which the radiating fibres frequently terminate at their innermost extremity. 2. Rods torn from their fibres. 3. Fibres of optic nerve; c, fine—a and b, varicose. 4. Two cones torn from their processes, d; with attached rod, a, at outer end; c, nucleus.—Magnified 350 diameters. (*Kölliker.*)

are much altered by all reagents; and a very common change consists in their end presenting a hook-like curve or a slight enlargement. (Figs. 298 and 295, *m'*.)

The *cones* may be regarded as rods terminating internally in a conical or pyriform body (instead of a filament), whose length equals one-half the thickness of the bacillar layer, and its breadth being $\frac{1}{5000}$ to $\frac{1}{2666}$ of an inch. Each of these cones has an external thicker and larger, finely granular extremity, often ventricose, gradually diminishing in size, and passing into a common rod without a point; and a shorter inner portion, inclosing an elongated or pyriform, more opaque, and brilliant body, $\frac{1}{6000}$ to $\frac{1}{4000}$ of an inch long. Kölliker, however, sees in these cones, as just described, only a *cell with a nucleus*. (Fig. 298, 4.)

Fig. 299.



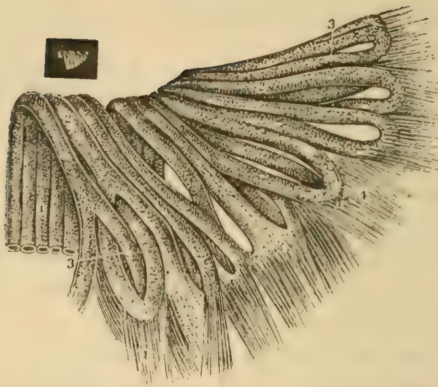
Bacillar layer from without. 1. At the "yellow spot" (only cones). 2. At the border of the same. 3. From the middle of the retina. *a.* "Cones," or vacuities corresponding with them. *b.* "Rods" of the "cones," whose terminal surface is often placed rather more deeply than that of the proper "rods," *c.*—Magnified 350 diameters. (*Kölliker.*)

The rods and cones are arranged vertically upon the retina, like palisades in close apposition, one of their ends being directed towards the choroid membrane, and the other towards the granular layer. The appearance of the cones and rods when the bacillar layer is seen from without (the cones alone existing over the macula lutea), is shown by Fig. 299.

3. The *eighth pair* is the nerve of hearing. The acoustic nerve is composed of fibres $\frac{1}{6000}$ to $\frac{1}{2400}$ of an inch in diameter, which are very easily destroyed, and are invested by a very delicate perineurium. Hence it has been called the *portio mollis*. Among these fibres in the trunk, and in both the vestibular and cochlear branches, there occur numerous apolar, unipolar, and bipolar cells, $\frac{1}{600}$ to $\frac{1}{171}$ of an inch in diameter. Kölliker suggests that the first two kinds are truncated bipolar cells. Similar but smaller cells are also found in the cochlea, as well as in the nervous twigs in the vestibule.

The *vestibular nerves* finally break up into a rich bundle of smaller and frequently anastomosing branches, which appear to terminate ultimately in fine twigs composed of from two to ten primitive fibres, $\frac{1}{12000}$ to $\frac{1}{8000}$ of an inch thick. In the *sacculus* we find the *otoliths* in immediate relation with the nervous expansion. These are composed of innumerable hexahedral prisms of carbonate of lime.

Fig. 300.



A highly magnified view of a small piece of the lamina spiralis, showing the manner in which the nerves leave their perineurium as they anastomose; the natural size of the piece is seen on the side of the figure. 1. Portion of the auditory nerve. 2, 2. Osseous canals in the zona ossea of the lamina spiralis. 3, 3. Anastomoses in the zona mollis. 4, 4. The neurilemma leaving the nervous loops, and expanding into the zona membranacea.

Fig. 301.

Bipolar ganglion-cell from the zonula ossea of the lamina spiralis of the pig.—Magnified 350 diameters. (After *Corti.*)

The *cochlear nerve*, having entered the cavity of the osseous zone from the canal of the modiolus, forms a plexus (Fig. 300) of dark-bordered fibres, $\frac{1}{8000}$ of an inch in diameter, containing an aggregation, at a definite spot, of, at first, $\frac{1}{120}$ of an inch wide, of bipolar, oval, minute ($\frac{1}{1090}$ to $\frac{2}{750}$ of an inch), and pale ganglion-cells; and which probably intercept all the fibres of the cochlear nerves in their course. (Fig. 301.)

The dark-bordered fibres proceeding from the external side of these cells are again disposed in anastomosing, and afterwards in parallel flattened bundles. The fibres actually terminate by being pale, $\frac{1}{12000}$ of an inch in diameter, and finer; and then ceasing, there being no loops. (*Corti.*)

Thus both the auditory and the optic nerves have a ganglion at their periphery, which probably receives the impressions, while the nerve-fibres merely serve to conduct them to the brain.

II. Structure of the Nervous Centres.

The nervous centres are—

1. The spinal cord.

2. The encephalon: consisting, 1*st*, of the medulla oblongata and the pons Varolii; 2*dly*, the cerebellum; 3*dly*, the cerebral ganglia; and, 4*thly*, the cerebral hemispheres.

The centres consist of the white and the gray nerve-substance combined; the former being made up of nerve-fibres alone (and vessels), the latter of nerve-cells and nerve-fibres combined, together with (in the cerebellum and cerebral hemisphere) a granular substance and free nuclei. The gray substance is also abundantly supplied with vessels. The whole cerebro-spinal axis (*i. e.* the centres just mentioned) is also enveloped by three distinct membranes; which will be considered after the structure of the former has been described (p. 468).

Fig. 302.

Transverse section of human spinal cord through the middle of the lumbar enlargement, showing on the right side the course of the nerve-roots, and on the left the position of the principal tracts of vesicular matter. *A, A.* Anterior columns. *P, P.* Posterior columns. *L, L.* Portion of lateral columns. *a.* Anterior median fissure. *p.* Posterior median fissure. *b, b, b, b.* Anterior roots of spinal nerves. *c, c.* Posterior roots. *d, d.* Tracts of vesicular matter in anterior column. *e.* Tracts of vesicular matter in posterior column. *f.* Spinal canal, not normal. *g.* Substantia gelatinosa.

I. Structure of the Spinal Cord.

While the white substance of the cord is composed almost exclusively of nerve-fibres, the gray portion is formed, in almost equal proportions, of nerve-fibres and cells. A section of the cord shows the gray matter forming a column in the central part of each half of the cord (Fig. 302), whose transverse section is of a crescentic form, its two extremities being termed the anterior and the posterior horns. The white substance surrounds and incloses the gray on every side, except towards the median line, where the gray matter projects through the white, and thus comes into contact from the opposite sides, constituting the *gray commissure.* This does not normally, in man, contain any canal in its centre, but is constituted principally of nerve-cells of a yellowish color, and is called the *substantia grisea centralis.* The white matter in the two halves of the cord merely comes nearly into contact behind the gray commissure; but in front of the latter it is continuous from one side to the other, constituting the anterior or *white commissure.* The portion of each half of the cord between the anterior median fissure and the anterior roots of the spinal nerves, is termed the *anterior column;* that between the posterior median fissure and the posterior roots, the *posterior column;* and the remaining portion between the anterior and posterior roots, the *lateral column.* At the extremity of the posterior horns of the gray matter is a more transparent layer, containing a preponderance of smaller nerve-cells—the *substantia gelatinosa* of Roland. The gray columns vary considerably in their size and form in different parts of the cord, as shown by transverse sections; it being most abundant in the lumbar, and next in the cervical region.

1. On examining the intimate structure of the cord, we find in the *white matter* two sets of fibres, the longitudinal and the horizontal, or transverse.

The *longitudinal* fibres are found in all situations except the anterior commissure, are unmixed with horizontal fibres in every part, as a rule, and everywhere run parallel to each other, without either interlacement or being collected into smaller fasciculi. They increase from below upwards, since they successively pass inwards towards the gray matter in their descent. They average $\frac{1}{6000}$ to $\frac{1}{4000}$ of an inch, and the size of each fibre remains very nearly the same in the white substance; no divisions or other alterations in diameter being found. These fibres are probably continuous with

the horizontal fibres next to be mentioned, being intermediate between the latter and the fibres of the cerebrum.

The *transverse* or horizontal fibres occur, 1*st*, in the lateral and posterior columns adjoining the horns of the gray substance; 2*dly*, in the white commissure; and, 3*dly*, at the point of entrance of the roots of the nerves. The first will be described with the gray substance.—The fibres in the *white commissure* come from the anterior columns, and, bending obliquely inwards, cross in front of the gray commissure to the opposite side. The white commissure is thus a *decussation* of the anterior column, and not a commissure, as generally understood. The decussing fibres measure $\frac{1}{10000}$ to $\frac{1}{4000}$ of an inch, and decrease as they diverge in the anterior horns of the gray matter.—The fibres in the *roots* of the spinal nerves are contained in larger fasciculi, either horizontal, or slightly ascending between the longitudinal fibres to enter the anterior and posterior horns of the gray matter, where we shall again meet them. The fibres do not all communicate with the longitudinal; and in their posterior roots about two-thirds of them measure $\frac{1}{3000}$ to $\frac{1}{1500}$ of an inch, and one-third of them $\frac{1}{1000}$ to $\frac{1}{4000}$ of an inch. In the anterior roots about three-fourths of the fibres measure from $\frac{1}{2000}$ to $\frac{1}{1091}$ of an inch, and one-fourth of them $\frac{1}{5000}$ to $\frac{1}{4000}$ of an inch. They, however, constantly decrease in size as they proceed through the white matter, and when they enter the gray matter the motor fibres are only $\frac{1}{3000}$ to $\frac{1}{2000}$ of an inch, while the sensory are but $\frac{1}{10000}$ to $\frac{1}{4285}$ of an inch.

2. The nerve-fibres of the *gray* substance of the cord are very numerous, constituting, in any case, one-half of its bulk, or more. They present the same characters as the fibres of the white substance, except that they are not, on the average, more than one-half as thick ($\frac{1}{15000}$ of an inch).

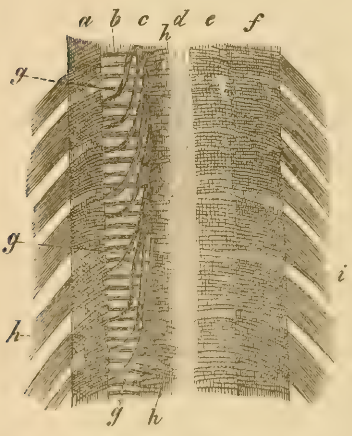
As they pass among the nerve-cells of the gray matter, some of the motor fibres have no connection with the processes of the cells; but continue to run in the anterior horns to the lateral parts of the anterior commissure, and become continuous with the fibres of the latter. Thus some of the motor fibres are connected with the longitudinal fibres of the anterior columns, with a total decussation. Many of the motor fibres, however, take no part in this decussation, especially those which enter the anterior horns most externally. These penetrate transversely to various depths (one-half or more), then curve upwards, and finally appear as longitudinal fibres. Thus

another portion of the motor fibres is continuous with the longitudinal fibres of the *same* side, without any decussation.

It should be added that though the motor fibres diminish in size after entering the cord, till they enter the gray matter, where they are about $\frac{1}{6000}$ of an inch in diameter, they again enlarge as they emerge from the latter, but never so as to attain their original diameter.

The *sensitive* roots also penetrate the white matter of the cord to the posterior horns of the gray matter, and proceed, without any direct connection with the nerve-cells, quite through the *substantia gelatinosa* into the *substantia grisea.* From this point some of the fibres bend upwards nearly at a right angle, and proceed to become longitudinal fibres in the posterior columns. Another portion of them penetrates, in a fascicular form, between the above-mentioned longitudinal bundles, further forwards, losing themselves in the posterior and the lateral columns, and also extending into the gray commissure probably on the opposite side. (Fig. 303.)

Fig. 303.



Vertical and antero-posterior section through the cord, midway between the gray cornua and the point of entrance of the roots of the nerves. *a.* Posterior column, with the sensitive roots (*h*), traversing it. *b.* Substantia gelatinosa. *c.* Prolongations of the posterior roots, which bend round in front of the substantia gelatinosa, and run longitudinally in order there to join more particularly the posterior column. *d.* Basis of the posterior cornua, with the ends of the horizontal portion of the sensitive roots apparent (from their being cut across). *e.* Anterior cornua, with the large nerve-cells (the spots), and also the horizontal and divided continuations of the motor roots. *f.* Anterior column traversed by the motor roots (*i*).—Magnified 25 diameters. (*Kölliker.*)

The sensory fibres also decrease in size as they traverse the cord, till they reach the gray commissures; being $\frac{1}{1500}$ of an inch in the roots themselves, never more than $\frac{1}{3000}$ of an inch in the *substantia gelatinosa*, $\frac{1}{12000}$ to $\frac{1}{4000}$ of an inch in the *substantia grisea*, and only $\frac{1}{15000}$ to $\frac{1}{10000}$ of an inch in the gray commissure. They, however, also increase on leaving the latter, to from $\frac{1}{10000}$ to $\frac{1}{3000}$ of an inch, and afterwards become longitudinal fibres.

Besides the motor and sensory fibres, there are still others in the

gray substance, not referable to the roots, and which for the present may be termed *special fibres of the spinal cord.*

The *gray substance of the cord*, in addition to the fibres just described, contains cells presenting various forms, but all being invariably furnished with processes, which, after repeatedly branching, ultimately terminate in extremely fine pale fibrils, like the finest axis-fibres. Kölliker distinguishes three classes of nerve-cells. 1. The cells of the central gray substance (Fig. 304) measure $\frac{1}{3000}$ to $\frac{1}{1500}$ of an inch; are always pale and granular, with multiple nuclei and branching pale processes. These constitute the principal bulk of the central gray substance. 2. The cells of the *substantia gelatinosa* resemble the preceding, except that they are of a faint yellowish color, and have one to three processes, and simple nuclei. 3. Well-marked cells are seated especially at the apex of the anterior horn (Figs. 279, 280), though also occurring in other portions of the anterior, and in less number in the posterior, horn; while they are never met with in the *substantia gelatinosa* and the gray commissure. All these cells are $\frac{1}{400}$ to $\frac{1}{200}$ of an inch in diameter, with nuclei of $\frac{1}{2400}$ to $\frac{1}{1500}$ of an inch; frequently contain brown pigmentary matter, and have from two to nine or even more branched processes, $\frac{1}{3000}$ to $\frac{1}{2400}$ of an inch in diameter at their origin. These processes may be traced to a length of $\frac{1}{120}$ to $\frac{1}{50}$ of an inch, and terminate in fine fibrils, scarcely more than $\frac{1}{30000}$ of an inch thick, all of which are contained within the gray substance.

Fig. 304.

Cells from the gray central substance of the cord in man.—Magnified 350 diameters. (*Kölliker.*)

Do the nerve-fibres of the roots of the spinal nerves terminate in the white and gray matter of the cord? or do they all ascend to the brain? Volkmann maintains that they terminate in the cord, and has carried most physiologists with him. We, however, regard Kölliker's reasons for the belief that they proceed to the brain, as far more satisfactory. That the nerve-fibres become attenuated on entering the cord, has already been shown. And the further fact

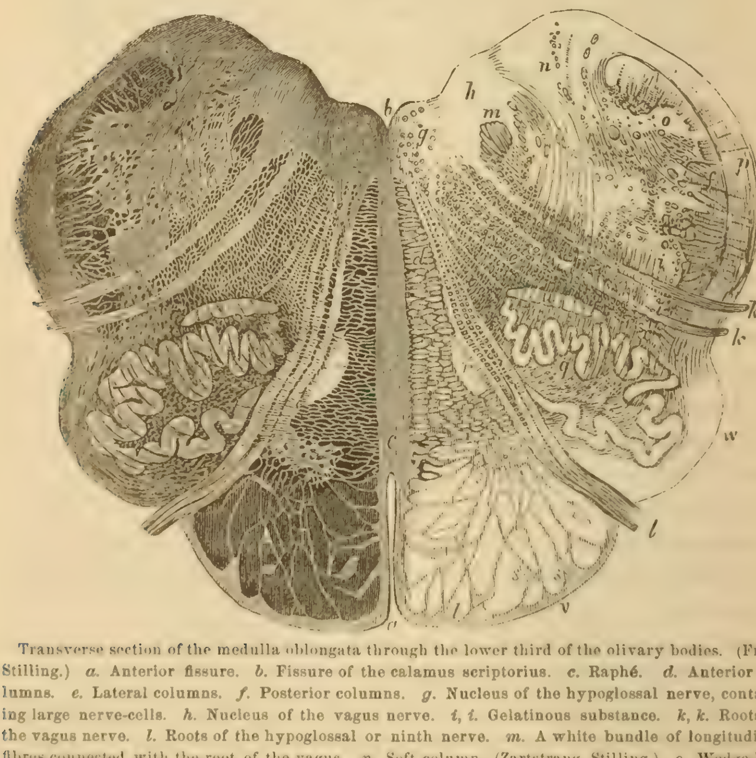
that the white substance of the cord constantly increases from below upwards, and that the enlargements of the cord depend mainly upon the gray substance, has an important bearing on this question. Moreover, no connection has been discovered between the nerve-fibres in the cord, and the processes of the cells of its gray matter. Still, it by no means follows that these cells may not act on the fibres sent among them; and experimental physiology at present demands the admission that they do impart motor impulses to them, at least in the production of reflex or diastaltic motions.

II. Structure of the Encephalon.

1. *The Medulla Oblongata and Pons Varolii.*

The medulla oblongata and pons Varolii constitute a very important part of the encephalon, since ten of the twelve pairs of encepha-

Fig. 305.



Transverse section of the medulla oblongata through the lower third of the olivary bodies. (From Stilling.) *a.* Anterior fissure. *b.* Fissure of the calamus scriptorius. *c.* Raphé. *d.* Anterior columns. *e.* Lateral columns. *f.* Posterior columns. *g.* Nucleus of the hypoglossal nerve, containing large nerve-cells. *h.* Nucleus of the vagus nerve. *i, i.* Gelatinous substance. *k, k.* Roots of the vagus nerve. *l.* Roots of the hypoglossal or ninth nerve. *m.* A white bundle of longitudinal fibres connected with the root of the vagus. *n.* Soft column. (Zartstrang, Stilling.) *o.* Wedge-like column. (Keelstrang, Stilling.) *p.* Transverse and arciform fibres. *q.* Nucleus of the olivary bodies. *r.* The large nucleus of the pyramid. *s, s, s.* The small nuclei of the pyramid. *u.* A mass of gray substance near the nucleus of the olives (Oliven-Nebenkern), *u, q, r,* are traversed by numerous fibres passing in a transverse semicircular direction. *v, w.* Arciform fibres. *x.* Gray fibres. (4 diam.)

lic nerves (all but the first and second pairs) rise from these and the *crura cerebelli.* It is not consistent, however, with the object of this work to describe their complicated structure at length. A section of the former is shown by Fig. 305.

1. The *white* substance of the medulla oblongata is in part continuous with that of the cord, and partly distinct from it; and everywhere consists of nerve-fibres of the same dimensions as those of the cord. The *anterior columns* of the cord (Fig. 306) are partly continued into the outer part of the corpora pyramidalia; and partly ascend both internally and externally to the olivary body, and proceed through the pons Varolii into the posterior corpora quadrigemina on the one hand and the *tegmentum* of the crura cerebri on the other. The *lateral columns* divide, on reaching the medulla, into three branches; (1,) ascending mostly into the crura cerebelli, and, in small part, into the *tegmentum;* (2,) decussating in two or three

Fig. 306.

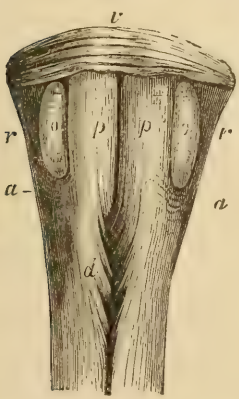


Fig. 307.

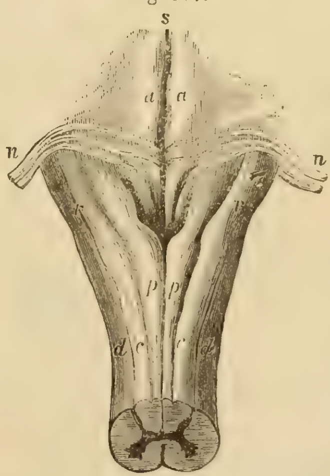


Fig. 306. Anterior view of the medulla oblongata. *p, p.* Corpora pyramidalia decussating at *d.* *o, o.* Olivary bodies. *r, r.* Restiform bodies. *a, a.* Arciform fibres. *v.* Lower fibres of the pons Varolii.

Fig. 307. Posterior view of the medulla oblongata. *p, p.* Posterior pyramids, separated by the posterior fissure. *r, r.* Restiform bodies composed of (*c, c*) posterior columns, and (*d, d.*) lateral. *a, a.* Olivary columns as seen on the floor of the fourth ventricle, separated by (*s*) the median fissure, and crossed by some fibres of origin of (*n, n*) the seventh pair of nerves.

fasciculi with that of the other side (decussatio pyramidum), and forming the principal bulk of the anterior pyramids; and (3,) appearing between the posterior columns at the bottom of the fourth

ventricle as the posterior pyramids, and being thence continued on the floor of the ventricle, side by side, into the *tegmentum* of the crura cerebri. The *posterior columns* (Fig. 307) in part constitute the corpora restiformia, and finally enter the crura cerebelli: while the remainder, situated externally to the posterior pyramids, also enters the tegmentum of the *crura cerebri*. There is also a system of *horizontal* nerve-fibres which are independent of the cord, and which are probably commissural.

2. The *gray matter* of the medulla oblongata is collected into larger masses principally in three situations: viz., in the olivary and the restiform bodies, and in the floor of the fourth ventricle. 1. The gray matter of the *olivary body* constitutes a capsule, closed on all sides except the inner: and is entirely isolated from all other gray substance. It is traversed by very numerous nerve-fibres of the horizontal system. 2. The gray matter of the *restiform bodies* may be regarded as a continuation of the posterior horns of the spinal cord, and even presents some resemblance to their *substantia gelatinosa*. (*Stilling*.) 3. The gray substance of the floor of the fourth ventricle is a continuation of the central gray matter of the cord, and forms a tolerably thick layer from the calamus scriptorius to the *aqueductus Sylvii*. The portion in the anterior half of this ventricle belongs properly to the pons Varolii.—Besides these three masses of gray matter, there are other very small ones in the medulla oblongata, not requiring a description here. In no case are the nerve-fibres (the horizontal, or those from the cord) known to be continuous with the processes of the nerve-cells.

Do the ten pairs of encephalic nerves, mentioned on page 461, rise from the gray matter of the medulla oblongata to which they have been mostly traced by Stilling and others? We deem it most probable that they rise in the corpora striata and optic thalami, for reasons assigned by Kölliker.[1] That the gray matter, however, influences the nerve-fibres which traverse it, is at the same time most probable.

2. *The Cerebellum.*

The *gray* matter of the cerebellum occurs only on the surface of the convolutions, in the *nucleus dentatus*, and the roof of the fourth ventricle: all the rest being white substance. The latter consists of parallel nerve-fibres, presenting all the characters of central

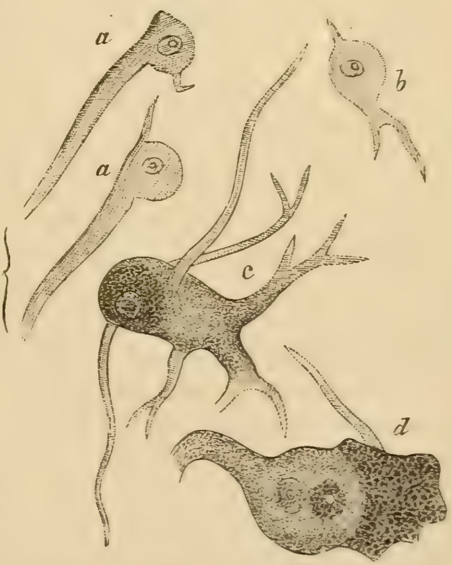
[1] Pp. 377–8.

fibres (softness, proneness to become varicose, easy isolation of the axis-fibre, &c.); and do not require a special description. They average $\frac{1}{6000}$ of an inch; the extreme being $\frac{1}{10000}$ and $\frac{1}{3000}$ of an inch.

The *gray substance* of the *convolutions* of the cerebellum alone requires a special description. It everywhere consists of a layer externally gray, and internally of a rusty color (ferruginous layer). The latter contains nerve-fibres and large masses of *free nuclei.* The fibres are continuations of those of the white substance; and extending through the ferruginous layer to the gray layer, they break up into numerous fine fasciculi, so interlaced that the whole ferruginous layer is penetrated by a close but delicate network of fine fibres somewhat resembling the terminal plexus of the acoustic nerve. The free nuclei lie in the meshes formed by the nerve-fibres; being from $\frac{1}{6000}$ to $\frac{1}{3000}$ of an inch in diameter, and frequently exhibiting a distinct nucleolus and sometimes other granules.—The nerve-fibres, however, do not terminate in the ferruginous layer. Becoming attenuated mostly to a diameter of $\frac{1}{10000}$ of an inch, they enter the external gray layer to terminate in its inner stratum, which contains nerve-fibres and well-marked large nerve-cells; while the outer portion contains no nerve-cells, but merely a finely granular, pale, light-yellowish substance, agreeing in all respects with the already described contents of the nerve-cells.

The cells generally in the gray matter resemble those of the cord, already described. Entirely dif-

Fig. 308.



Ganglion-cells, with their processes, nuclei, and nucleoli. *a, a.* From the deeper part of the gray matter of the convolutions of the cerebellum. The larger processes are directed towards the surface. *b.* Another form from the cerebellum. *c, d.* Others from the posterior horn of gray matter of the dorsal region of the cord. These contain pigment which surrounds the nucleus in (*c*). In all these specimens the processes are more or less broken. (Magnified 200 diameters.)

ferent, however, from these smaller elements are the large cells discovered by Purkinje, and which are found only in the innermost portions of the gray, next to the ferruginous layer. (Fig. 308, *a.*) These measure $\frac{1}{750}$ to $\frac{1}{400}$ of an inch, are round, pyriform, or oval, with finely granular colorless contents, and 1 to 4 (generally 2 or 3) long and much branched processes; the largest of these being given off from the sides of the cells which look from the ferruginous layer, and extending nearly to the outer surface ($\frac{2}{3}$ or $\frac{3}{4}$ of its thickness), and producing a striation seen in horizontal sections. At their origin these processes are sometimes $\frac{1}{6000}$ of an inch thick, and very finely granular or delicately striated. As they proceed they become more homogeneous, and divide into numerous extremely slender branches, the ultimate ones being scarcely $\frac{1}{60000}$ of an inch thick. Kölliker has traced these processes even $\frac{1}{60}$ of an inch without coming to the finest subdivisions. While their principal prolongations are thus continued through the gray layer, they give off their branches at acute or right angles, producing a second striation, crossing the one before-mentioned at a greater or less angle.

The *crura cerebelli* contain nerve-fibres only; being a continuation of the white matter of the cerebellum itself.

3. *The Ganglia of the Cerebrum.*

Of these there are three pairs; the corpora quadrigemina, the optic thalami, and the corpora striata. (Fig. 309.) All these are bulky collections of gray substance and nerve-fibres. The latter connect these ganglia on the one hand with the cerebellum and medulla oblongata, and on the other with the hemispheres of the cerebrum. They present no histological peculiarities.

Nor is it necessary particularly to describe the *gray* matter in these three ganglia. Kölliker considers it as *made out* that the fine nerve-fibres traceable to the outermost part of the *ventricular nucleus* (the posterior and inferior portions) of the corpus striatum, *terminate there*, and *do not proceed to the cerebral hemispheres.* He also regards it as probable that the fibres becoming attenuated in the optic thalamus and the tubercula quadrigemina, terminate in like manner. At the same time, it appears to be the fact that nerve-fibres rising in the cerebral hemispheres also become attenuated and terminate in these same ganglia.

Other parts connected with these ganglia, and containing gray

matter, are—the *substantia nigra* of the crus cerebri, the *commissura mollis*, *the floor of the third ventricle* immediately behind and beneath

Fig. 309.

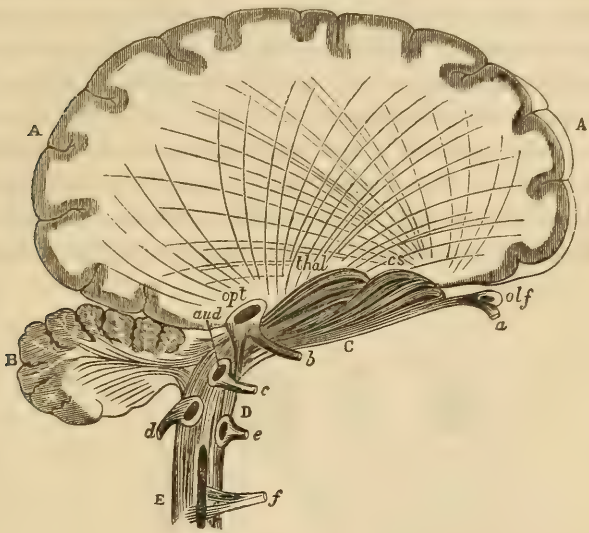


Diagram of the mutual relations of the principal encephalic centres, as shown in a vertical section. A. Cerebrum. B. Cerebellum. C. Sensori-motor tract, including the olfactory ganglion (*olf*), the tubercula quadrigemina, or optic ganglia (*opt*), and the auditory (*aud*), with the thalami optici (*thal*) and the corpora striata (*cs*). D. Medulla oblongata. E. Spinal cord; *a*, olfactory nerve; *b*, optic; *c*, auditory; *d*, pneumogastric; *e*, hypoglossal; *f*, spinal accessory. Fibres of the medullary substance of the cerebrum are shown connecting its ganglionic surface with the sensori-motor tract.

the anterior commissure, and the *tuber cinereum*. The *pineal body* contains pale rounded apolar cells and scattered nerve-fibres, and generally also a considerable quantity of sabulous matter (principally carbonate of lime, with phosphate of lime and magnesia). The *pituitary* body contains in its anterior reddish lobe no nervous elements at all, but the "elementary tissues of blood-vascular glands." (*Ecker.*) The posterior smaller lobe consists of a fine granular substance with nuclei and bloodvessels; and also fine varicose nerve-fibres, which, like the vessels, descend from the infundibulum.

4. *The Cerebral Hemispheres.*

The *white substance* of the hemispheres of the brain consists entirely of nerve-fibres, $\frac{1}{10000}$ to $\frac{1}{4000}$ of an inch (average $\frac{1}{6000}$ of an inch) in diameter. These never form plexiform interlacements

or fasciculi, but all run in parallel and generally straight lines, and certainly proceed from the ganglia of the cerebrum and the corpus callosum to the gray substance of the central convolutions. There are also other fibres crossing the former at right angles (commissural fibres), of whose origin nothing satisfactory is yet known.

The *gray matter* of the cerebrum is principally situated externally, covering the convolutions, and being $\frac{1}{8}$ to $\frac{1}{6}$ of an inch thick. It contains in its whole thickness both nerve-cells and nerve-fibres; besides a large amount of granular homogeneous substance precisely like that of the cerebellum. It is, however, conveniently divided into three layers; 1, an internal *yellowish-red;* 2, a middle, pure *gray;* and 3, an external, *white.* The first mentioned, however,

Fig. 310.

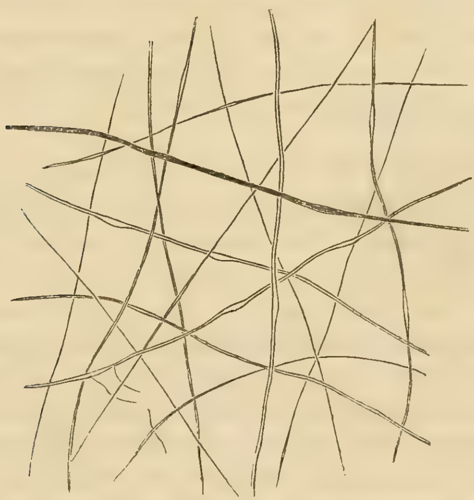
Nerve-cells from the internal portions of the gray layer of the convolutions of the human cerebrum. *a*. Larger. *b*. Smaller. *c*. Nerve-fibre with axis-cylinder.—Magnified 350 diameters. (*Kölliker.*)

constituting almost one-half the entire thickness of the gray matter, may itself be divided into four layers; 1, a yellowish-red layer (inner part); 2, the inner white streak; 3, yellowish-red layer (outer part); 4, outer white streak. Then come the two remaining layers above; 5, the pure gray, and 6, the white. The nerve-cells throughout the gray matter have from 1 to 6 processes giving off numerous branches, ultimately becoming very fine pale fibrils of $\frac{1}{30000}$ of an

inch. In the external white layer the cells are few and small, with one or two processes, and scattered in an abundant finely granular matrix. The pure gray layer most abounds in cells, and which are also closely aggregated in a granular matrix. Some of them are very small ($\frac{1}{4000}$ to $\frac{1}{2400}$ of an inch), appearing frequently as scarcely more than nuclei; while there are others larger, even to $\frac{1}{600}$ of an inch. (Fig. 310.) Most of them have from 1 to 6 processes (usually 3, 4, or 5). Finally, in the innermost yellowish-red layer, the cells are less, though still very abundant, and present the same characters as those of the gray substance.

The *nerve-fibres* of the gray substance of the convolutions, come from the white substance of the hemispheres, and penetrate the yellowish-red layer in all directions, but more especially parallel to

Fig. 311.



Finest nerve-tubes of the superficial white substance of the human cerebrum.—Magnified 350 diameters. (*Kölliker.*)

the surface; and consequently they cross the main fasciculi. It is these horizontal fibres which produce the white streaks before mentioned; and it is in the external white streak that the fasciculi entering the gray substance are lost. The fibres, however, which do not take a horizontal direction, proceed onwards even through the pure gray layer, and into the external white layer. Here they take a horizontal direction, and form several superimposed layers

of the finest fibres crossing each other in various directions. (Fig. 311.) Many of these fibres also form *loops*, and return into the gray-red substance, again, as first shown by Valentin (p. 448).

Kölliker has not been able to discover any connection between these fibres and the cells of the gray matter of the convolutions; though the existence of such a connection is nowhere else so probable as here. Doubtless the nerve-fibres originate here, if anywhere in the central organs. Professor Domrich has, however, traced the many-rayed cells of the cerebellum into nerve-fibres, as he asserts; and Kölliker has found divisions of the nerve-fibres in the cord, but never in the encephalon. It is probable that the fibres of the corpus callosum and the commissural fibres in general, commence in cells in one hemisphere and terminate in the other.

Gray matter is also found in the cerebrum at other points; viz., in the anterior portions of the body of the *corpus callosum*, above the septum lucidum, the fornix, and the corpus striatum; occasionally on the surface of the corpus callosum between the raphé and the striæ, and which is continued into the fascia dentata of the pes hippocampi, and in the hippocampus itself.

The Membranes and Vessels of the Nervous Centres.

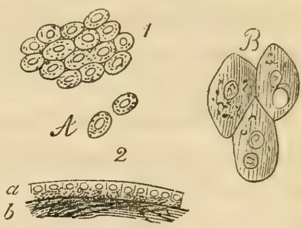
The whole cerebro-spinal axis, just described, is inclosed in three membranes; 1, the internal, or *pia mater;* 2, the middle, or *arachnoid;* and 3, the external, the *dura mater.*

1. The *pia mater* is the vascular membrane of the nervous centres. It is composed of collagenous tissue (p. 279, 6), and conducts the vessels into the nervous substance. Hence it is in intimate contact everywhere with the cord, and covers all the elevations and depressions on the surface of the encephalon; excepting alone the floor of the fourth ventricle, above which it stretches across. On the cerebrum it is more vascular and more delicate than upon the cord. It penetrates into the brain only at one point, viz., the transverse fissure of the cerebrum—where, under the name of the *velum interpositum* it invests the vena magna Galeni and the pineal body; then forms the *tela choroidea superior*, the *choroid plexus* of the third ventricle, and the *vascular plexuses of the lateral ventricles*, which are continuous with the pia mater at the base of the brain. It contains fusiform, bright-yellow, or brown pigment-cells, both in its spinal and its encephalic portions. They are so abundant in the cervical region as not unfrequently to give the membrane a brown

or even blackish color. They are also found in the medulla oblongata and the pons Varolii, and still more anteriorly.

The vascular plexuses, just named, in the ventricles are composed mostly of vessels, and are covered by an epithelium where they are not adherent to the walls of the ventricles. This consists of a single layer of roundish polygonal cells, $\frac{1}{1800}$ to $\frac{1}{1200}$ of an inch in diameter, and $\frac{1}{4000}$ to $\frac{1}{3000}$ of an inch thick; containing, besides the rounded nucleus, many yellowish granules, and one or two dark round oil-drops measuring $\frac{1}{12000}$ to $\frac{1}{6000}$ of an inch. It is not probable that they are ciliated, as asserted by Valentin. Underneath the epithelium is a simple membrane; and next, the vessels connected by a hyaline homogeneous substance (p. 108).

Fig. 312.



The ependyma in man. A. From the corpus striatum; 1, from the surface; 2, from the side; *a*, epithelial cells; *b*, nerve-fibres lying beneath. B. Epithelium-cells from the commissura mollis.—Magnified 350 diameters. (*Kölliker.*)

All the portions of the ventricles not covered by the continuations of the pia mater, have a special lining membrane, the *ependyma ventriculorum.* This is a simple conoidal epithelium (Fig. 312[1]); and it is separated from the brain-substance by a filamentous layer $\frac{4}{1200}$ to $\frac{1}{240}$ of an inch thick, of embryonic areolar tissue. Virchow and Kölliker did not find it to exhibit ciliary motion, as asserted by Purkinje and Valentin.

2. The *arachnoid membrane* does not consist of two lamellæ, as usually described; but of a single one, the internal one of authors. This is an extremely delicate transparent membrane, corresponding in extent to the *dura mater.* It is made up of lamellæ of fasciculi of white fibrous tissue, surrounded by fine elastic fibres. In the spinal canal it is loosely adherent to the pia mater, by fasciculi of areolar tissue, so that a space, called the *subarachnoid space*, exists between it and the latter membrane, and which is filled with the cerebro-spinal fluid. In the cranium it is much more adherent to the pia mater. Thus, there is no continuous subarachnoid space upon the brain, but numerous larger and smaller spaces only partially communicating. The larger of these spaces (between the cerebellum and medulla oblongata, under the pons Varolii, the crura cerebri, and the fossa Sylvii), open directly into the subarachnoid space of the spinal cord; while the remaining ones do not.

The arachnoid has no connection with the lining membrane of the ventricles. Finally, the free surface of the arachnoid is covered by a simple scaly epithelium. The *external lamina*, so called, of the arachnoid, is merely a precisely similar epithelium upon the dura mater.

3. The *dura mater* of the *cord* (theca vertebralis), is a whitish-yellow, sometimes glistening, firm, and somewhat elastic membrane, formed of parallel fasciculi of white fibrous tissue, and of a fine elastic fibrous network in almost equal proportions. It is twice as thick posteriorly as anteriorly; and in the latter position is pretty firmly united to the anterior common vertebral ligament, while it is free on the sides and behind. Internally, the dura mater is covered by a simple scaly epithelium alone, there being no external lamella of the arachnoid. The *ligamentum denticulatum* has no epithelium, and presents a structure precisely like that of the dura mater.

In the *cranium*, the dura mater is thicker and whiter than in the spinal canal, and consists of two layers: 1, the external or periosteal, and 2, the internal. The former, more laxly united to the latter at an early period, is whitish-yellow and rough, and attached more or less firmly to the bones, and supports the larger meningeal vessels. The internal layer, or proper dura mater, is less vascular, whiter, has generally a glistening tendinous aspect, and its surface is quite smooth. Between the two layers, with few exceptions, the *sinuses* are situated. The processes of the dura mater (the falx cerebri and cerebelli, and the tentorium) are prolongations of the internal layer. The simple scaly epithelium covering the dura mater consists of cells of $\frac{1}{2400}$ to $\frac{1}{2000}$ of an inch, with rounded or elongated nuclei $\frac{1}{6000}$ to $\frac{1}{4000}$ of an inch in diameter.

Vessels and Nerves of the preceding Membranes.—The *dura mater* of the cord has in its substance but few vessels, though numerous arteries and veins of the cord perforate it. The dura mater of the encephalon is far more vascular, as already described, especially in its external or periosteal layer. The sinuses in it are simple excavations lined with an epithelium.

The *arachnoid* membrane, whether of the brain or the spinal cord, contains no proper vessels.

The *pia mater* both of the brain and the cord, has a tolerably rich capillary plexus of its own, besides supporting the very copious ramifications of the vessels of the nervous substance.

Lymphatics are said to have been demonstrated by Fohmann and Arnold in the pia mater, on the surface both of the cerebrum and cerebellum, and in the choroid plexus—an observation needing confirmation.

Nerves also are found in the membranes of the nervous centres. The dura mater of the cerebrum has nerves (twigs of the eighth pair), pretty nearly following the course of the meningeal arteries, and especially upon the middle meningeal. A twig from the third branch of the fifth pair is distributed principally to the bones. Another from the fifth pair is called the nerve of the tentorium cerebelli, and goes to the larger sinuses of the dura mater. (*Pappenheim.*) Neither Kölliker nor Purkinje has detected any nerves in the theca vertebralis; though they occur in the periosteum of the vertebral canal, and on the arteries going to the vertebræ and the cord.

The *arachnoid* contains no proper nerves, but the vessels penetrating it do, especially at the base of the brain. The *pia mater* of

Fig. 313.

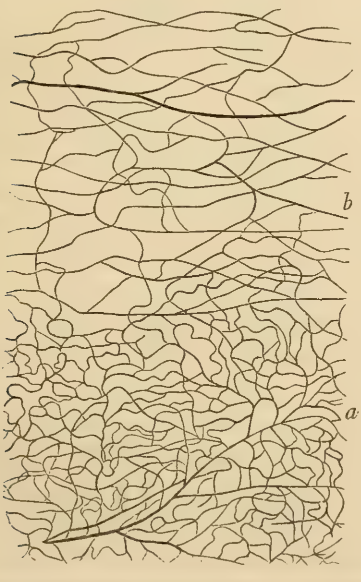


Fig. 314.

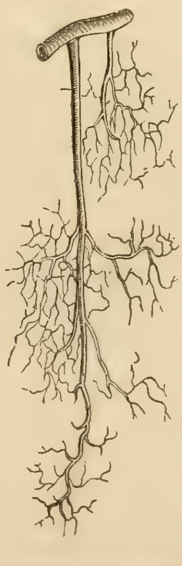


Fig. 313. Vessels of the cerebral substance of the sheep, from one of Gerlach's injections; *a*, of the gray; *b*, of the white substance. (*Kölliker.*)

Fig. 314. Two terminal arteries from a branch on the surface of a convolution of the cerebrum, and dipping vertically inwards; and exhibiting the mode of origin and distribution of capillaries in the gray cortical layer. From an injected specimen. (Magnified 30 diameters.)

the cord is richly supplied with plexuses of fine nerve-fibres which accompany the vessels. At the base of the brain, many similar plexuses occur on the arteries of the circle of Willis, which are distributed in twigs $\frac{1}{400}$ of an inch in diameter through the entire cerebral pia mater, following its vessels, but not those of the cerebellum.

The vessels of the *cord* and *encephalon* themselves on leaving the pia mater, are supplied to the gray matter much more abundantly than to the white substance; the capillary plexus being closer (and the capillaries themselves of less calibre), to which the dark color is in part due. The interstices of the capillaries in the white substance are $\frac{1}{800}$ by $\frac{1}{500}$ of an inch. (*E. Weber.*) In the sheep's brain the breadth of the interstices of the gray substance is three or four times less than in the white. (*Gerlach.*) (Fig. 313.) The finest capillaries in the cord measure $\frac{1}{5454}$ of an inch, and in the brain, $\frac{1}{6000}$ of an inch. The manner in which the terminal arteries merge into the capillaries on entering the gray matter of the convolutions from the pia mater is shown by Fig. 314.

Chemical Composition of the Nervous Centres.

The composition of the elements of the nerve-fibres has already been given, so far as it is understood (p. 430). The composition of the white and gray matter of the encephalon will now be specified.

Vauquelin states that the spinal cord and medulla oblongata have the same composition as the cerebrum, except that they contain much more fat, with less albumen, ozmazome, and water. The analyses of the encephalon alone will be here given; and those of Von Bibra will be adopted as the most recent and reliable.[1]

The following is Von Bibra's analysis of the gray and the white matter, separately, of the brain of a man aged 30 years, who died of phthisis:—

	Gray substance of cerebral hemispheres.	White substance of corpus callosum.	White substance of medulla oblongata.
Water	83.57	69.19	71.55
Fat	6.43	20.43	14.67
Solids, exclusive of fat . . .	10.00	10.38	13.78

[1] Comparative Investigations of the Brain of Man and the Mammalia. Mannheim, 1854.

The following is his analysis of the entire encephalon of the fœtus at different stages, and that of a child at 6 months:—

	At 10 weeks.	At 12 weeks.	At 14 weeks.	At 18 weeks.	At 20 weeks.	At 21 weeks.	At 37 weeks.	Child 6 months.
Water . . .	85.10	86.71	86.24	86.90	86.03	85.93	87.90	82.96
Fat	1.26	0.99	1.53	1.06	1.07	1.23	3.06	6.99
Solids, exclusive of fat	13.64	12.30	12.23	12.04	12.60	12.84	9.04	10.04

Thus the gray substance contains more *water* than the white, the water being replaced in the latter by fat. The water in the brain of the fœtus is also far more abundant than in the adult, the difference being made up by an increase of fat in the latter. The sudden increase of fat for a short time before and after birth, is a fact of much physiological interest.

The quantity of *fat* in the brain is found to be constant, within certain limits. It is not diminished in diseases occasioning emaciation in other parts, nor is it increased in the lower animals by fattening. It seems to be established that the fat has important relations to the functions of the brain. Its amount is a little less in old men than in adults in the prime of life. L'Heritier's analyses also show that it increases from infancy up to adult age.

In man, other mammalia, and birds, the medulla oblongata contains more fat than the cerebellum and the cerebrum. There is the most fat, relatively and absolutely, in the hemispheres of the human brain; next in other mammals, and then in birds, amphibians, and fishes.

An analysis of the brain-fat shows it to consist of cerebric acid 20 to 21 per cent., cholesterine 30 to 33 per cent., and a series of fatty acids constantly varying in composition, and which contain no nitrogen or sulphur. The white substance contains more cerebric acid and cholesterine than the gray, and consequently less of the other fats. The quantity of cerebric acid seems to diminish as we descend the animal scale, and is less in the fœtus and the infant than in the adult.

Phosphorus is also contained in the brain-fat; except the fatty acids, which solidify at a temperature below 38½° (Fahr.). In a man who died at 59 years of age, of Bright's disease, the phosphorus in the whole brain amounted to 1.68 per cent. of the fat. There was the most in the hemispheres, the cerebellum, and pons Varolii (1.83 per cent.); and the least (1.54 per cent.) in the optic thalami

and corpus callosum. Von Bibra concludes that the amount of phosphorus in brain-fat is very nearly the same in man, other mammals, and birds; that its amount is not essentially modified in insanity, in old age, in very young persons, and even in the embryo; and that there is no reason to believe that the intelligence is especially connected with its amount. The fat of the gray matter of the brain, however, contains rather more phosphorus than that of the white matter.

The other *solids, besides fat*, alluded to, are albumen, another albuminoid substance not coagulable by boiling, and the mineral substances usually met with in other organs and in the formative fluids. Sulphates are, however, almost entirely absent, and the chlorine varies much in amount. Of the earthy phosphates, the medulla oblongata contains a larger proportion than other parts of the encephalon. They are also more abundant in the brain of amphibians and fishes than in the higher animals. In fact, all the inorganic constituents are least abundant in the brain of man and other mammals, greater in birds, and greatest in amphibians and fishes. The ratio of the potash to the soda in the human brain is nearly intermediate between the ratios occurring in the ashes of flesh and blood respectively (p. 395).

Functions of the Nervous System.

For definite information on this subject, reference must be had to the treatises on physiology. It may here only be remarked that, so far as motion is concerned, the gray matter of the spinal cord is probably the centre of reflex (or diastaltic) motion; the ganglia of the cerebrum are the centre of the emotional (and sensational) actions; and the cerebral hemispheres are the source of voluntary motion. On the other hand, some part of the cerebrum (and, most probably, the optic thalami) is the centre of sensation; while the sympathetic influences ascribed to the ganglionic nervous system are not peculiar to it, but inhere also in the ganglionic nerve-fibres in the spinal nerves; these fibres also being the probable channel through which emotions affect the organic functions, and especially that of secretion—as of the milk, the lachrymal fluid, &c.

The cerebral hemispheres are also the centre of the intellectual and moral faculties; while the cerebellum presides over the coordination of the voluntary motions, but takes no part in the mental phenomena. Certain facts point to the conclusion that it is also the

seat of the sexual impulse; but this function cannot yet be regarded as established.

Pathological States of the Nervous Centres.

Certain pathological conditions of the nerve-fibres and the nerve-cells have already been specified (pp. 433 and 437). The encephalon and cord are also affected by softening and various other abnormal states—as from the development of tumors, &c. But the consequent lesions of motion, sensation, and the intellectual faculties, are too numerous and complicated to be described here.

CHAPTER XI.

THE MEMBRANES.

THE synovial membranes (p. 344), the vaginal sheaths, and the bursæ mucosæ (p. 418, 3), have already been described. Those to be described in this chapter are:—

1. The cutaneous membrane, or skin.
2. The mucous membranes.
3. The serous membranes.

Each of these consists of the same histological elements from within outwards; viz., 1, the corium; 2, the basement-membrane; and 3, the epithelium. Thus no tissues, not already described, occur in them.

Both the skin and the mucous membranes present elevations and

Fig. 315.

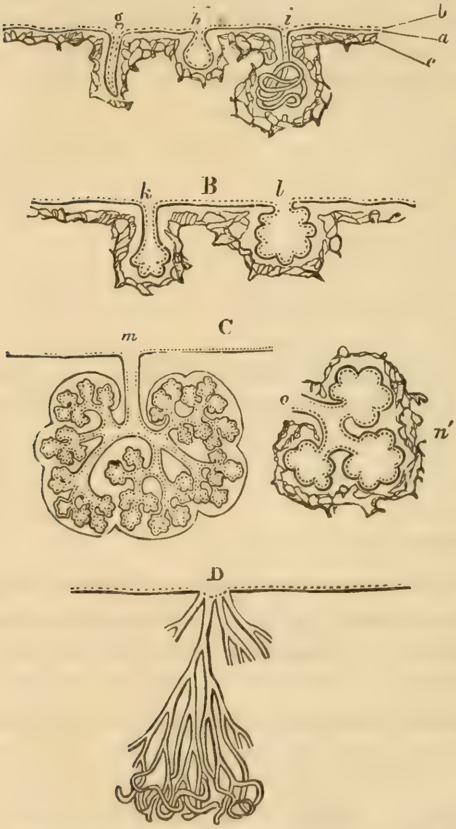
Typical forms of papillæ of the skin and mucous membrane, and intestinal villi. *a*. Basement-membrane. *b*. Epithelial layer of secreting cells, mostly detached. *c*. Layer of capillary vessels in the corium of the skin or mucous membrane. *d*. Simple papilla or villus. *e*, *f*. Compound (branched) papillæ.

depressions on their surface; the former being termed papillæ and villi, and the latter, glands. Fig. 315 represents the forms of the papillæ, and Fig. 316 of the glands.

I. The Skin.

1. The *corium* of the skin, or innermost layer, constitutes the greater part of its entire thickness in most parts of the body; and this alone is converted into leather when the skins of the lower animals are tanned. Its relation to the basement-membrane and the epithelium is shown in a vertical section of the skin (Fig. 317); which also shows a sweat gland in the subcutaneous areolar tissue, or superficial fascia, described on page 290. It is a tough, slightly elastic membrane, composed of white and yellow fibrous (areolar) tissue; to which must also be added smooth muscular fibres, bloodvessels, nerves, and lymphatics, in great abundance. In the inner portions of the corium, the fibres are interwoven in a manner to give indications of lamination. The elastic fibres abound in the corium; but much more in the subcutaneous areolar tissue. The *smooth muscular* fibres also abound in some portions of the latter, constituting the dartos, so called, under the skin of the scrotum; and a similar layer under the skin of the prepuce, of the perineum, and the ante-

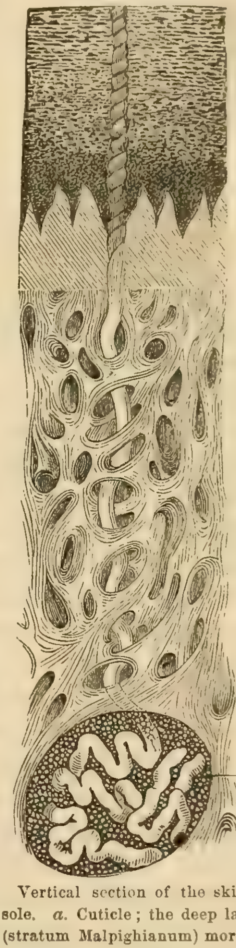
Fig. 316.



Typical forms of glands. A. *Simple glands*; *a*, *b*, *c*, as in the last figure; *g*, follicle or follicular gland; *h*, sacculus, or saccular gland; *i*, tubular gland, the tube coiled up. B. Simple racemose glands; *k*, of tubular, and *l* of saccular form. C. Compound racemose glands; *m*, entire gland; showing branched duct and lobular structure; *n′*, a lobule detached, with *o*, branch of duct proceeding from it. D. Compound tubular gland.

rior part of the body of the penis. They also exist under the skin of the areola around the nipple of the female, forming circular bundles of a yellowish-red color, even $\frac{1}{36}$ of an inch thick, and extending both circularly and perpendicularly into the nipple itself. But smooth muscular fibres are also found in the *superficial* portions of the corium, and, in fact, in every part where hairs occur (*arrectores pili*, *Eylandt*,) forming flat bundles $\frac{1}{1200}$ to $\frac{1}{750}$ of an inch broad, which are placed singly or in pairs near the upper part of the hair-follicles and sebaceous follicles. Eylandt finds the bundles to be only $\frac{1}{6000}$ of an inch thick, and has never seen more than one pass to a hair-follicle. Henle makes them $\frac{1}{3000}$ of an inch thick. Rising from the superficial part of the corium, they extend obliquely outwards, and are inserted into the hair-follicles close behind, and near the base of the sebaceous glands (p. 267 and Fig. 135).

Fig. 317.



Vertical section of the skin of sole. *a.* Cuticle; the deep layers (stratum Malpighianum) more colored than the upper, and their particles rounded; the superficial layers more and more scaly. *b.* Papillary portion. *c.* Principal portion of corium. *d.* Sweat-gland lying in a cavity on the deep surface of the skin, and imbedded in globules of fat. Its duct is seen passing to the surface. (Magnified 40 diameters.)

The *inner surface* of the corium is rough and areolated, to correspond with the outer surface of the superficial fascia into which it merges. Its *external* surface is also very far from being level, from the development here of the tactile papillæ. The reddish-gray, external, superficial portion of the corium, containing the upper portion of the hair-follicles and cutaneous glands, and the terminal expansions of the vessels and nerves of the skin, is sometimes called the papillary portion of the corium. The tactile *papillæ*, its most important element (Fig. 318), are small, semi-transparent, flexible, but tolerably solid elevations of the external surface of the corium, usually of a conical or clavate form, but sometimes presenting numerous

points (compound papillæ, Fig. 319). They are very numerous on the palm of the hand and the sole of the foot, and are situated upon

Fig. 318.

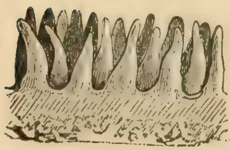


Fig. 319.

Fig. 318. Papillæ of the palm, the cuticle being detached. (Magnified 35 diameters.)

Fig. 319. Compound papillæ of the surface of the hand with two, three, and four subdivisions. *a*. Base of a papilla. *b*, *b*. Their separate processes. *c*, *c*. Processes of papillæ whose base is not visible.—Magnified 60 diameters. (*Kölliker.*)

ridges visible to the naked eye. E. H. Weber found upon the *vola manus*, on a surface 1 line square, 81 compound, or 150 to 200 smaller papillæ, disposed with tolerable regularity in two principal series, each having two to five papillæ in the transverse direction; placed on linear elevations $\frac{1}{120}$ to $\frac{1}{30}$ of an inch broad by $\frac{1}{240}$ to $\frac{1}{72}$ of an inch high—the *ridges* of the corium.

Elsewhere, the papillæ are more irregularly scattered, either very closely together, as in the labia minora, the clitoris, the penis, and the nipple, or somewhat more widely apart, as on the extremities (except the places above named), on the scrotum, the neck, chest, abdomen, and back.

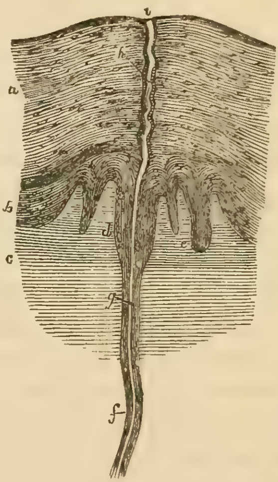
The *size* of the papillæ varies much. The shortest ($\frac{1}{792}$ to $\frac{1}{480}$ of an inch), occur on the face; and next ($\frac{1}{960}$ to $\frac{1}{720}$ of an inch), on the female breast, the scrotum, and at the root of the penis. In most other situations, they are $\frac{1}{264}$ to $\frac{1}{396}$ of an inch long. The longest ($\frac{1}{360}$ to $\frac{1}{240}$ of an inch), are found on the palm of the hand, the sole of the foot, the nipple (where they are generally of the compound kind), the anterior and posterior extremities of the bed of the nail ($\frac{1}{168}$ to $\frac{1}{120}$ of an inch), and the labia minora ($\frac{1}{240}$ to $\frac{1}{120}$ of an inch). The diameter of the papillæ at the base generally equals, or is somewhat less than the length. In the shortest, above-mentioned, it exceeds the length by $\frac{1}{3}$ or more; and hence they resemble warts or even short ridges. In the largest papillæ the breadth is $\frac{1}{3}$ to $\frac{1}{2}$ the length.

The distribution of the bloodvessels and nerves in the papillæ will be described on page 483.

Finally, the *thickness* of the corium varies from $\frac{1}{96}$ to $\frac{1}{8}$ of an inch, being $\frac{1}{48}$ to $\frac{1}{16}$ of an inch in most places. It is thinnest ($\frac{1}{98}$ to $\frac{1}{60}$ of an inch) in the *meatus auditorius externus*, the eyelids, the red border of the lip, and the *glans penis* and *clitoridis;* and thickest ($\frac{1}{24}$ to $\frac{1}{12}$ of an inch) on the back, chin, upper and lower lip, the *alæ nasi*, the ball of the sole, the extremity of the great toe, over the scapula and the nates, and on the heel (even $\frac{1}{12}$ to $\frac{1}{8}$ of an inch).

2. The *basement-membrane* of the skin has been demonstrated only in certain parts; and by Kölliker it is not recognized as one of its histological elements in the adult; though he admits it exists in the embryo. It is merely a layer of simple membrane accurately covering every part of the external surface of the corium, and supporting the epithelium.

Fig. 320.



Vertical section of the skin of the thumb, showing the epidermis and outer layer of the corium; treated with acetic acid. *a*. Horny layer of the epidermis. *b*. The Malpighian layer. *c*. Corium. *d*. Single papilla. *e*. Compound papilla. *f*. Epithelium of the perspiratory duct, continuous with the Malpighian layer of the epidermis. *g*. Canal of the same through the corium. *h*. Its passage through the horny portion of the epidermis. *i*. Perspiratory pore.

3. The *epithelium* of the skin has already been in a general way described; it being a compound scaly epithelium (p. 240). Its outer layer, including the harder portion removable by a blister, is usually termed the epidermis, or cuticle, or *horny layer;* and the remaining internal portion, the *stratum Malpighii*, or *rete mucosum.* The latter consists of several layers of cells, the innermost being $\frac{1}{3700}$ to $\frac{1}{2000}$ of an inch long, and $\frac{1}{5000}$ to $\frac{1}{4000}$ of an inch broad, and placed perpendicularly to the surface of the corium. Sometimes several layers of perpendicularly arranged cells occur, giving the deepest portion of the *stratum Malpighii* a striated appearance. Upon these, several layers of elongated or round cells follow. (Figs. 146 and 320.) The cells in the outermost layer become flattened, and thus merge into those of the cuticle or horny layer. The contents of these cells are never quite fluid, but are finely granulated, the granules invariably diminishing in the more external cells. In the negro these granules are colored, as has been shown by Fig. 68;

especially those clustered round the nuclei of the cells. In the white races, the granules are also darker in certain parts of the body, and the cells become pigment-cells, therefore, as already described; as in the areola and the nipple (especially during pregnancy and after bearing children), in the linea alba, and the face during pregnancy, &c. (p. 136). In the negro, even the *horny* layer (cuticle) is also inclined to yellow or brownish; while in the white races it is entirely colorless, except in the parts and circumstances just mentioned. It consists usually of many layers of horny plates, the lowermost of which suddenly merge into the subjacent uppermost cells of the rete Malpighii. That these plates are still flattened cells, and contain a very minute quantity of viscid fluid, is proved by the addition of acetic acid and potassa, which cause them to swell up and assume the form of vesicles, sometimes, though seldom, containing a rudimentary nucleus. In the lower and middle parts of the cuticle, these plates are pretty regularly polygonal (4, 5, or 6 sided); in the upper layers they present more irregular outlines, and often appear wrinkled and folded. They vary from $\frac{1}{1500}$ to $\frac{1}{750}$ of an inch in diameter. Upon the *glans penis* and the outer side of the *labia minora*, the largest are $\frac{1}{750}$ to $\frac{1}{600}$ of an inch, and on the *labia majora* $\frac{1}{1200}$ to $\frac{1}{750}$ of an inch in diameter. All these larger cells are distinctly nucleated.

These plates being applied to each other horizontally, give the cuticle a distinct lamination. The most superficial laminæ are parallel to the general surface of the corium, while the deepest take a direction parallel to the surface of the papillæ. Thus depressions corresponding to the papillæ in form appear on the inner surface of the cuticle (Figs. 321 and 328), and into which the papillæ, covered by the stratum Malpighii, projected.

The *thickness* of the *entire* epithelium of the skin varies in different parts; viz., it is $\frac{1}{900}$ to $\frac{1}{600}$ of an inch on the chin, cheeks, and brow, on the eyelids, and in the external auditory passage; $\frac{1}{600}$ to $\frac{1}{300}$ of an inch on the bridge of the nose, the breast and nipple of a female, the back of the toes and the fingers, on the neck and back, on the inner and outer side of the thigh, the scrotum, and the labia minora.

It is $\frac{1}{300}$ to $\frac{1}{192}$ of an inch on the edge of the eyelids, the male chest and nipple, the hairy scalp, the chin, penis, prepuce, and glans penis; $\frac{1}{192}$ to $\frac{1}{120}$ of an inch on the red external portion of the lips,

Fig. 321.

Under surface of the cuticle, detached by maceration from the palm; showing the double row of depressions in which the papillæ have been lodged, with the hard epithelium lining the sweat-ducts in their course through the corium. Some of these are contorted at the end, where they entered the sweat-gland. (Magnified 30 diameters.)

and the back of the hand; $\frac{1}{120}$ to $\frac{1}{84}$ of an inch on the flexor side of the fingers and toes.

It is $\frac{1}{36}$ to $\frac{1}{24}$ of an inch on the palm, and $\frac{1}{16}$ to $\frac{1}{9}$ of an inch in the sole of the foot; though here the varieties are greatest.

As compared with the horny layer (cuticle) alone, the *stratum Malpighii* is in some localities always $2\frac{1}{2}$ to $4\frac{1}{2}$ times the thicker; viz., in all parts of the face, in the hairy scalp, the penis, the scrotum, the nipple, and the skin of the thorax in man; in the labia majora and minora, and on the back of the hand and neck. In the glans penis the stratum Malpighii and the cuticle are of equal thickness. In other parts of the body the two layers are either equal in thickness, or the horny layer is 2 to 5 (or sometimes 10 to 12) times as thick as the Malpighian.

The thickness of the *stratum Malpighii* (at the base of the papillæ) varies between $\frac{1}{1750}$ and $\frac{1}{75}$ of an inch. When thicker than the horny layer, it averages $\frac{1}{300}$ of an inch; when thinner, $\frac{1}{1200}$ to $\frac{1}{600}$ of an inch.

Chemical Composition and Physical Properties of the Skin.

The general composition of the *cuticle*, as one of the horny tissues, has already been indicated (p. 235). Its cell-walls are insoluble in water, but concentrated alkalies and concentrated sulphuric acid easily dissolve them; and hence the skin, if wetted with these agents, feels slippery and greasy. The cuticle contains less sulphur than the hair and nails; and hence, perhaps, salts of lead, mercury, and bismuth color the hair, but not the epidermis. Nitrate of silver colors it violet or brownish black; the oxide, chloride, and black sulphuret of silver being formed from the chloride of sodium and the sulphur it contains. The tissue of the cuticle is, however, quite unchanged, the microscope merely detecting minute dark granules between its elements. But strong solutions of the iodide and of the cyanuret of potassium remove the color, by dissolving away the horny plates themselves.

The horny structure of the epidermis permits no fluids, except those which act chemically upon it, to pass through it; while it readily takes up gaseous matters, or easily vaporizable substances, as ether, alcohol, acetic acid, ammonia, ethereal solutions of chloride of iron, and alcoholic solutions of acetate of lead. It also gives all these off by cutaneous evaporation. (*Krause.*) Water, ointments, and even solid matter (sulphur, cinnabar), pass through the uninjured cuticle; but here there is a mechanical intrusion, in and through the sweat-ducts and hair sacs, to the stratum Malpighii, which, on the contrary, is easily penetrated by fluids. Hence, also, the very ready occurrence of absorption after the separation of the horny layer and the superficial portion of the Malpighian, by a blister.

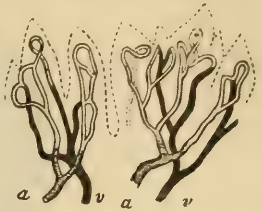
The *corium* affords gelatine on boiling, from the osteine contained in its white fibrous tissue. It putrefies with difficulty, and not at all when tanned. Its toughness and slight elasticity have already been mentioned.

Vessels of the Skin.

The arteries in the subcutaneous areolar tissue give off many branches to the hair-papillæ (p. 259), to the fat-lobules (Fig. 188), and the smooth muscular fibres. More externally, they supply the sweat- and the sebaceous glands (Figs. 138, 135), and the inner portion of the corium; and finally penetrate into its outer part, and

into the papillæ themselves, where they terminate in a close capillary network. This consists—1*st*, of a horizontal portion lying immediately under the surface covered by the Malpighian layer, composed of vessels $\frac{1}{1200}$ to $\frac{1}{2400}$ of an inch, and of capillaries $\frac{1}{4000}$ to $\frac{1}{2400}$ of an inch in diameter, with narrow meshes; and, 2*dly*, of many loops of the finest vessels ($\frac{1}{4000}$ to $\frac{1}{3000}$ of an inch) given off to the papillæ. (Fig. 322.) Generally, each papilla has its own capillary loop, which runs either in its axis or near the surface, almost to its apex. The compound papillæ have several loops.

Fig. 322.



Vessels of the papillæ from the heel. *a*. Terminal arterial twig. *v*. Commencing vein. (Magnified 80 diameters.)

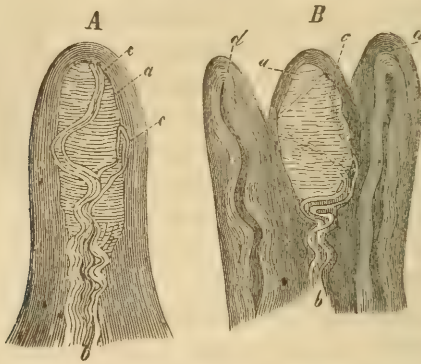
Lymphatic vessels also exist in the subcutaneous areolar tissue, and form a very close network of fine vessels in its outermost part, $\frac{1}{240}$ to $\frac{1}{180}$ of an inch in diameter.

The Nerves of the Skin.

But few nerves exist in the subcutaneous areolar tissue; but these, entering the corium, anastomose frequently, and form rich terminal plexuses. Of these, the deeper portions consist of fine branches, still containing many nerve-fibres, with wide meshes; while the superficial portions consist of fibres, either single or united in pairs, with narrow meshes. In this last there also occur (perhaps not in all the fibres) actual divisions of the nerve-fibres, generally at an acute angle, into two subdivisions; and from the plexus itself the fibres finally enter the base of the papillæ in pairs, running to their extremities, and then uniting in a loop. (Fig. 323.) The nerve-fibres in the papillæ vary from $\frac{1}{15000}$ to $\frac{1}{5000}$ of an inch. The axile or tactile corpuscles (corpuscula tactûs), described by R. Wagner (Fig. 323), are regarded by Kölliker as consisting of collagenous tissue, with much undeveloped elastic tissue. These exist only in a small proportion of the papillæ—about 1 in 4 of those on the first joint of the index finger. (*Meissner.*) They resemble a fir-cone in form, and occupy one-third to two-thirds of the width of the summit of the papilla, and one-fourth to three-fourths of its length. The conclusion of Wagner, that the papillæ without these corpuscles contain vessels only, but not nerves, needs further confirmation. At any rate, dark-bordered nerve-fibres are found in vascular papillæ without axile corpuscles, in the sole of the foot

and on the lips. His assertion, also, that the papillæ containing axile corpuscles have no vessels, is not confirmed by Kölliker's

Fig. 323.



Two papillæ from the extremities of the fingers, without epithelium, and *with* axile corpuscles (*a*) and nerves (*b*). *A*. Simple papilla with four nerve-fibres and two terminal loops (*c*). *B*. Compound papilla with two vascular points with capillary loops (*d*), and one nervous point with a terminal oo p (*e*). (*Kölliker.*)

observations, though it may apply to particular cases. It is very probable that the nerve-fibres do not in all cases enter into the papilla at all, but terminate in the superficial plexus at their base.[1]

Development of the Skin.

The *corium* consists, at first, entirely of cells; among, and from which, subsequently, the white fibres and the elastic tissue, the vessels and nerves are formed. It evidently grows from within outwards, so that the papillæ are developed last of all. It also continues to grow a long time after birth, it being only half as thick in children under seven years of age as in the adult. (*Krause.*) In embryo of two months, it is $\frac{1}{2000}$ to $\frac{1}{1200}$ of an inch thick, and presents tolerably distinct collagenous tissue. In the fourth month, the first lobules of fat appear, and the ridges of the hand and the sole of the foot.

The *epithelium* of the skin has its first layers developed by the metamorphosis of the most superficial of the primordial cells of the embryo. The outermost layers of these become the cuticle, and

[1] While Kölliker maintains that the nerve-fibres terminate in loops on the surface of the axile corpuscle, Meissner regards the cross striæ on the latter as the termination of the dark-bordered nerve-fibres.

those underneath, the stratum Malpighii. Then, as the former becomes detached, it is recruited from the latter. The extension in surface of the cuticle implies a series of desquamations in the embryo and the fœtus, and which must also occur after birth. The multiplication of the cells in the stratum Malpighii is certainly not by free cell-development (p. 120); since at no age are free nuclei present in it. (*Kölliker.*) In the embryo of five weeks, there are but two layers of cells instead of the epithelium; at fifteen weeks, three layers of cells, the two internal for the stratum Malpighii; in the fifth month, the latter consists of many layers of the smaller cells, and the cuticle of at least two, of polygonal flattened cells; and at the seventh month, these two layers are as sharply distinguished from each other as in adults. In the new-born infant the epithelium resembles that of the adult, except that it is more easily separated from the corium by maceration, and that the stratum Malpighii is disproportionally thick, and the cuticle very delicate.

The desquamations of cuticle during embryonic life, already alluded to, aid in the formation of the *vernix caseosa*, already de scribed (p. 226); this consisting of the external epidermic cells mixed up with the sebaceous secretion of the skin, and containing hairs; and which, especially from the sixth month onwards, covers the whole surface of the fœtus. It varies greatly in quantity in the new-born child; sometimes amounting to even 3½ drachms.

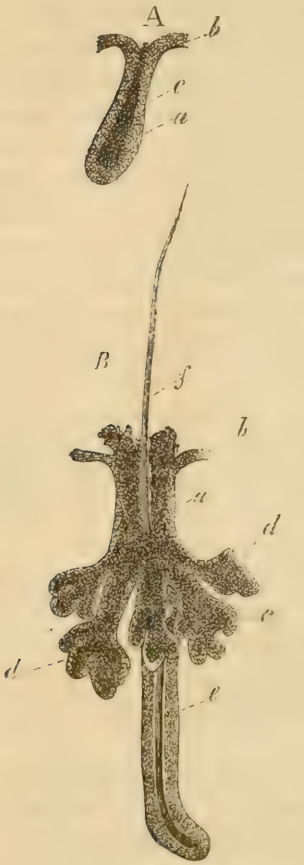
The pigment in the stratum Malpighii of the negro, appears after birth. The edges of the nails, and the surface around the nipple, become rapidly tinged black; the genital organs become colored on the third day, and the whole body on the fifth and sixth. (*Camper.*) In Europeans also, the pigment in the areola is gradually developed during the first year.

The *growth* of the corium presents no peculiarities. The cuticle is constantly being detached and repaired, and is thus constantly growing. The cells of the stratum Malpighii are developed from plasma exuded from the bloodvessels of the corium; and of which a determinate quantity always exists among these cells, and even those of the cuticle also. In the deep fold of the skin surrounding the *glans penis* and *clitoridis*, this continuous desquamation and reproduction of the cells of the cuticle produce the substance (not a secretion, as generally supposed) called the *smegma præputii.* In the male, however, the secretion of Tyson's glands may be mixed with it; but in the female, neither sebaceous nor any other glands

exist on either the prepuce or the glans clitoridis. (*Kölliker.*) Lehman's analysis of the smegma has already been given (p. 227).

The *corium* is *regenerated* if entirely removed; but the new development has neither papillæ nor ridges.

Fig. 324.



Sebaceous glands from the nose. A. Simple follicular gland without any hair. B. Racemose gland, having a common opening with a hair-sac; *a*, glandular epithelium, connected with *b*, the stratum Malpighii of the epidermis; *c*, contents of the glands, sebaceous cells, and free fat; *d*, the separate racemes of the compound gland; *e*, hair-sac (root-sheath), with the hair, *f*.—Magnified 50 diameters. (*Kölliker.*)

The epithelium, therefore, though regenerated in all cases when removed, has none of the usual elevations and depressions on both its surfaces, if the corium also has been removed. If the latter has remained uninjured, the new epithelium is rapidly produced and perfect, though it grows up as a whole from the corium below. This is well shown by the application of a blister.

Appendages and Accessory Organs of the Skin.

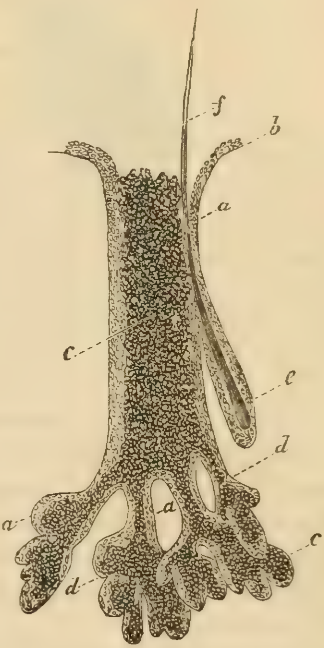
The appendages of the skin are the nails and the hair, already described (pp. 249--68). The accessory organs are: 1, the sebaceous glands; 2, the sweat-glands; and 3, the subcutaneous *bursæ mucosæ*.

1. The *Subcutaneous Bursæ Mucosæ* are merely simple or partially subdivided reticular *spaces* in the subcutaneous areolar tissue; as over the upper extremity of the olecranon, over the patella, &c. Their internal walls are smooth but uneven, and are formed of areolar tissue. They contain a viscid clear fluid, but have no epithelium.

2. The *Sebaceous Glands.*—These glands vary in form from the simple follicle (Fig. 324, A) to the racemose gland (Fig. 324, B). They occur principally upon the hairy parts of the body, opening in common with the

hair-sacs; and hence are sometimes termed the glands of the hair-sacs. They in fact occur, of the hairless parts, only on the labia minora, and the glans penis and clitoridis, and the prepuce of both the male and the female. The opening of the gland is sometimes common with that of the hair-sacs, sometimes it terminates in the latter, and sometimes the hair-sac is smallest, and the hairs come out through the glandular opening itself. (Fig. 324, B.) Generally, the small hair-sacs have the larger glands, and *vice versa*. The hairs of the scalp have the smallest, $\frac{1}{120}$ to $\frac{1}{77}$ of an inch in diameter, and these are simple follicles lodged in the superficial portion of the corium. The largest of all exist on the *mons veneris*, the *labia majora*, and the *scrotum*, where they are compound, and found in the deepest portions of the corium. Frequently two or more (even five) glands are connected with a single hair (Fig. 135); there being generally two in the scalp. The glands upon the nose (also the anterior half of the penis, and the areola), often attain to a colossal size and peculiar forms. (Fig. 325.)

Fig. 325.



A large racemose sebaceous gland from the nose with a little hair-sac opening into it. The letters (*a*—*f*) as in Fig. 324.—Magnified 50 diameters. (*Kölliker*.)

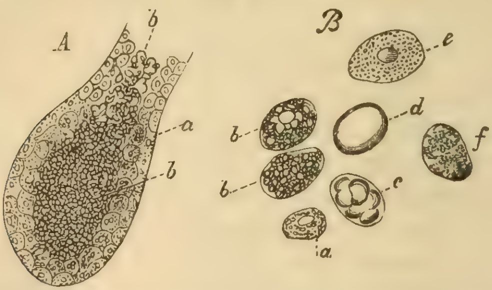
The sebaceous glands on the glans penis and the inner lamella of the prepuce, called Tyson's glands, sometimes occur in very small number, and sometimes in hundreds. Generally, ten to fifty are found on the prepuce, and mostly racemose; while on the glans they may be totally absent, or may exist in its anterior surface in great numbers (even to one hundred)—being here more simple.

The Meibomian glands in the eyelids must also be regarded as a larger kind of sebaceous gland. (Fig. 136.)

In their *minute* structure the sebaceous glands consist of—1, an external delicate layer of collagenous tissue (or basement-membrane—*Kölliker*), continued from the hair-sac, or the corium where

no hairs are present; within which are (2) masses of cells. The latter are arranged, first in a single, and rarely in a double layer, in contact with the basement-membrane; internally to which are other cells containing more fat, and which pass into the innermost of the cells which are larger ($\frac{1}{750}$ to $\frac{1}{423}$ of an inch), and so filled with colorless fat that they might be termed sebaceous cells. (Fig. 326.)

Fig. 326.



A. One of the cæca of a common sebaceous gland; *a*, epithelium sharply defined, but without any basement-membrane, and passing continuously into the fat-cells, *b* (their contours drawn too indistinctly), in the interior of the glandular tube. B. Sebaceous cells from A, and the cutaneous sebaceous matter; *a*, smaller nucleated cells, still more of an epithelial character, and containing but little fat; *b*, cells abounding in fat without visible nucleus; *c*, cell in which the fat is beginning to flow into one mass; *d*, cell with one fat drop; *e*, *f*, cell from which the fat has partially escaped.—Magnified 350 diameters. (*Kölliker.*)

The fat in them sometimes appears in the form of a single drop quite filling the cells; at others it still retains the form of distinct small drops. In the former case, they resemble the adipose cells. By endogenous development new cells are constantly produced in the bottom of the glands, and thus the pre-existing cells are thrust forward, and finally excreted through the neck of the gland upon the cuticle.

It appears that no *nerves* are distributed to the sebaceous glands. Nor are vessels distributed upon and between their lobules; while numerous vessels and capillaries exist around the glands.

These glands are *developed* from about the end of the fourth month of embryonic life, together with the hairs, since they appear as outgrowths or processes of the hair-sacs. Subsequently the processes become filled with the cells above described; and, finally, they open on the surface, and the structure of the gland is now complete. All the glands are at first simple, and most are so in the fœtus of seven months; and the compound are formed by processes proceeding from these. Sometimes a simple gland growing rapidly

completely surrounds a hair-sac on all sides, constituting a *glandular rosette.*

The sebaceous glands grow after birth. In fact, those of the *labia minora* do not exist at all at birth.

The composition and uses of the sebaceous secretion are specified on page 227.

3. *The Sudoriferous or Sweat-Glands.*—These consist of a single delicate convoluted tube, which secretes the sweat. They occur on the whole surface of the skin, except the concave side of the concha of the ear, and the external auditory meatus, the glans penis, the inner lamella of the prepuce, and a few other localities—and open upon it by numerous fine apertures.

Each sweat-gland may be divided into the *gland proper* and the *excretory duct.* (Figs. 138, 317, 321.) The *proper gland* is rounded or elongated, yellowish, or yellowish-red, and $\frac{1}{84}$ to $\frac{1}{60}$ of an inch in diameter. On the eyelids, however, and some other parts, they are only $\frac{1}{144}$ of an inch; while on the areola they are $\frac{1}{24}$ of an inch, and in the hairy parts of the axilla even $\frac{1}{24}$ to $\frac{1}{8}$ of an inch thick, and $\frac{1}{12}$ to $\frac{1}{4}$ of an inch broad. They are mostly lodged in the deeper layer of the corium, sometimes more superficially, and often in the subcutaneous areolar tissue among the hair-sacs.

Number of the Sweat-Glands.—Krause states that in a *square inch* of the skin there are between 400 and 600 glands on the back of the trunk, the cheeks, the upper arm, and the thigh; 924 to 1,090 on the anterior part of the trunk, on the neck, brow, forearm, back of the hand, and foot; 2,685 on the sole of the foot; and 2,736 on the palm of the hand. Their total number, including those of the axilla, is estimated at 2,381,248; and their volume, including the latter, 39,653 cubic inches.

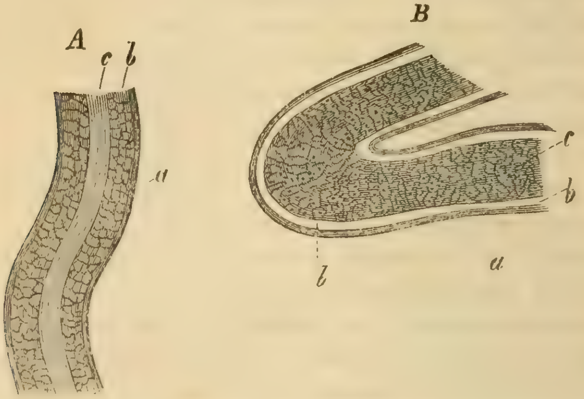
The aggregate *length* of all the *excretory ducts* of the sweat-glands in the body has been estimated by Wilson[1] at 28 miles.

1. In their minute structure, the *sweat-glands* usually consist of a single canal, pretty uniform in diameter throughout its length (which Krause once found to be $\frac{1}{16}$ of an inch), twined into a coil, and terminating on the surface on the interior of the latter in a slightly enlarged blind extremity. (Fig. 138.) Most of these, having *thin* walls, possess an external investment of embryonic collagenous

[1] Treatise on Diseases of the Skin.

tissue, with scattered elongated nuclei, and lined apparently by a basement-membrane, supporting a single, double, or multiple layer of polygonal cells, corresponding to the deep cells of compound conoidal epithelium, except that they generally contain a few fatty, and still more frequently yellowish or brownish, pigment-granules. (Fig. 327, *A*.) The rest, called the *thick-coated* canals, contain be-

Fig. 327.



Sweat-ducts. *A*. One with thin walls and a central cavity, without a muscular coat, from the hand: *a*, connective investment; *b*, epithelium; *c*, cavity. *B*. A portion of a canal without a cavity, and with a delicate muscular layer, from the scrotum: *a*, connective tissue; *b*, muscular layer; *c*, cells which fill the glandular canal, with yellow granules among their contents.—Magnified 350 diameters. (*Kölliker*.)

tween the two layers just described a middle layer of smooth muscular fibre-cells running longitudinally. (Fig. 327, *B*.) This is the case with the large glands of the axilla, of the root of the penis, and the nipple; and the cœcal extremity of the canal is supplied with muscular fibre-cells in the scrotum, labia majora, mons veneris, and some other parts.

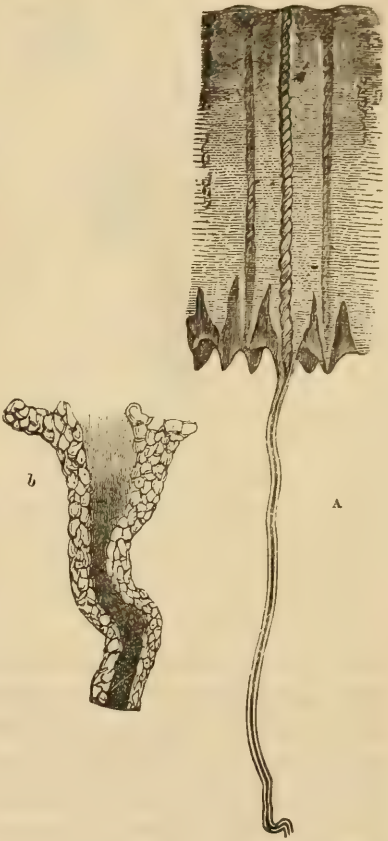
The size of the canal varies from $\frac{1}{560}$ to $\frac{1}{300}$, and averages about $\frac{1}{400}$ of an inch. The walls are $\frac{1}{6000}$ to $\frac{1}{4000}$ of an inch thick; the epithelium, $\frac{1}{2000}$; and the cavity, or *lumen*, $\frac{1}{3000}$ to $\frac{1}{1200}$ of an inch. The largest glands have canals $\frac{1}{400}$ to $\frac{1}{200}$ of an inch in diameter, with walls $\frac{1}{3000}$ of an inch thick.

The coils of the proper glands are penetrated by collagenous tissue interspersed with fat-cells; which supports the vessels, and unites the separate convolutions. The arrangement of the *vessels* is seen in Fig. 138. No *nerves* have yet been found in the glands.

2. The *sweat-ducts* are continuous with the upper end of the

glandular coil, and ascend vertically through the corium, penetrating *between* the papillæ into the epithelium. Here they twist like a corkscrew, and, according to the thickness of the cuticle, make two to sixteen spiral turns, and terminate by small round or funnel-shaped apertures ($\frac{1}{350}$ to $\frac{1}{240}$ of an inch), called the sweat-pores, on the free surface of the cuticle. (Fig. 328.) They retain their epithelium, consisting of at least two layers of cells, till they reach the surface of the corium. But while traversing the stratum Malpighii and the cuticle, they are merely bounded by layers of cells. Sometimes the excretory ducts of two glands unite into one. (*Krause.*)

Fig. 328.



A. Vertical section of the cuticle, from the heel detached by maceration. The epithelium of the sweat-duct continuous with the cuticle has been drawn out of the tube of basement-membrane, as far as to the gland, where it begins to be contorted. The cavity of the duct is seen dilating as it enters the cuticle, and then stretching up to the surface through the epidermic laminæ. The deep surface of the duct is continuous with the surface of the cavities in which the papillæ are lodged. *b.* Duct at its entrance into the cuticle, more highly magnified. (Magnified 35 diameters.)

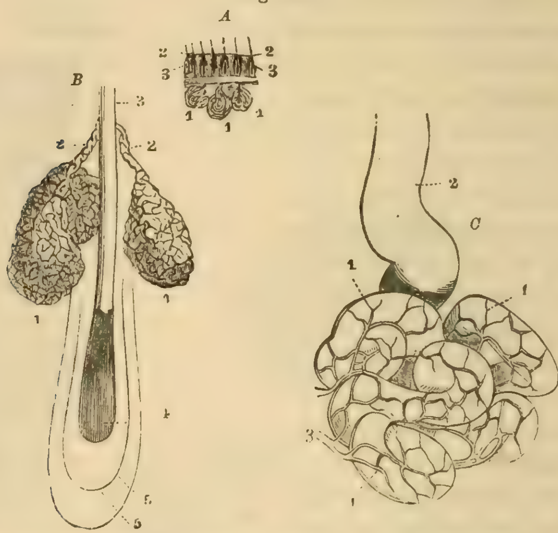
These glands are *developed* originally as solid flask-shaped processes of the stratum Malpighii projecting into the corium, and are very similar to the hair-sacs. They first appear in the fifth month of embryonic life. At the seventh month the sweat-duct is seen perforating the cuticle, and the gland has penetrated downwards to the inner portion of the corium, and become bent like a hook, indicative of the future coils. Soon after this, the gland acquires the appearance it presents in the adult, and probably no new ones are developed after birth.

The secretion afforded by the sudoriferous glands has already been described (p. 229).

The *ceruminous* glands of the ear may be regarded, histologi-

cally, as a variety of sweat-glands. Fig. 329 represents their various forms and relations to the hair-sacs. They exist only in the

Fig. 329.



Cutaneous glandulæ of external meatus auditorius. *A.* Section of the corium: 2, 2, hairs; 3, 3, superficial sebaceous glands; 1, 1, larger and deeper-seated glands, by which the cerumen is secreted. *B.* A hair perforating the epidermis at 3: 1, 1, sebaceous glands, with their excretory ducts (2, 2); 4, base of the hair in its double follicle (5, 5). *C.* Cerumen-gland formed by the contorted tube (1, 1) of the excretory duct (2); 4, vascular trunk and ramifications. The last two figures highly magnified; the first, 3 diameters.

cartilaginous portion of the external auditory meatus; being situated between the lining membrane of the passage and the cartilage, or the fibrous substance supplying its place, in a tough subcutaneous tissue containing but little fat.

The properties and uses of the cerumen have already been specified (p. 228); it being associated physiologically with the sebaceous secretion.

Functions of the Skin.

The skin fulfils a variety of functions.

1. Of protection, as the common tegument of the body.

2. As an absorbing organ. Gases are rapidly absorbed, and certain solid and fluid substances (p. 230). Even nutritious fluids are absorbed by the skin, as proved by the effects of nutritious baths. Here the fluid probably enters to the stratum Malpighii mainly through the sweat-ducts (p. 482).

3. Hence the skin is an aerating organ, as accessory to the lungs; oxygen being absorbed directly into its bloodvessels.

4. The skin is a secreting organ, affording the sweat and the sebaceous fluid.

5. The *contraction* of the skin is shown in the cutis anserina (so called), the erection of the nipple, and the wrinkling of the skin of the scrotum and the penis (p. 477).

6. But the skin manifests its most important function as the organ of the sense of *touch*. And it is a singular fact that all points of the skin are sensitive, though nerves cannot be demonstrated in all, or even in the majority, of the papillæ. Kölliker, however, finds that the same point is sometimes sensitive, and sometimes not so. Probably the nervous plexus at the base of the papillæ, and not those in the latter alone, are the media of the sensibility of the skin. The various modifications of tactile impressions, as those of pressure, warmth and cold, of orgasm, of tickling, pricking, burning, and pain, are not well accounted for. The thickness of the cuticle of a part, the paucity or abundance of nerves, the superficial or deep position of the nerve-fibres, the thickness or delicacy of their neurilemma, &c., must doubtless be taken into consideration; and, on the other hand, also, the agents producing the sensations named.

Pathological States of the Skin.

I. Pathological *colorations* of the *epithelium* of the skin have already been mentioned (p. 137). A local thickening of it from continued pressure constitutes the *clavus* or corn, and its other morbid states are mentioned on page 247.

In the *vesicular* diseases of the skin (pemphigus, &c.), an exudation of plasma, occurring from the vessels of the corium into the stratum Malpighii, causes a limited elevation of the cuticle. In eczema, herpes, and miliaria, the vesicles are very small. In ichthyosis the cuticle is much thickened.

II. The *corium* may (1) become generally atrophied in wasting chronic diseases (tuberculosis, syphilis, &c.); it becoming thinner and smoother on its surface, and the sebaceous and perspiratory glands, and the hairs, even, becoming atrophied or disappearing. Local atrophy may be produced by pressure and other causes.

2. New formations of areolar tissue in the corium (papilloma, &c.) have already been described (p. 247).

3. The corium is also the seat of disease in all the *exanthemata* (scarlatina, rubeola, &c.); most of them affecting the papillary portion more especially.

4. In variola, *papulæ* (so called) are first formed by exudation

from the capillaries mainly of the papillæ, which subsequently extends to the stratum Malpighii, producing a vesicle; and which finally becomes a pustule, since pus is formed in it. The centre of the pustule is depressed, from the fact that the opening of a sebaceous gland and a hair-sac penetrates there; and which does not allow the cuticle there to become detached and elevated, since it is connected with them.

5. In *measles*, *lichen*, and *prurigo*, papulæ alone are produced. There, also, the vascular injection is confined to the most superficial layers of the corium. In inveterate cases, however (of prurigo), the exudation extends to the deeper layers, and the hairs and sebaceous glands disappear.

6. In *verrucæ*, or warts, the papillæ become hypertrophied.

III. The *sebaceous glands* become, 1, hypertrophied in the *akrothymion*, or moist wart, and in *nævus pilosus*. 2. They become atrophied, or entirely disappear, when the hairs fall out, *i. e.* on bald places. 3. The *comedones* are mere distensions of the sebaceous glands and the hair-sacs with sebaceous matter, and are most frequent where the glands are largest, as on the nose, lips, chin, ear, areola, and scrotum. *Milium* is due to a similar distension of the sebaceous follicles alone; consisting of white spots on the eyelids, the root of the nose, the ear, the scrotum, &c. In both these cases, the apertures are obliterated or entirely closed. 4. Finally, *steatoma*, especially as it occurs on the scalp, is to be regarded merely as a colossal sebaceous gland distended with its secretion; and atheroma and meliceris, if occurring in the corium, must be referred to the same category.

5. The acarus folliculorum residing in healthy and distended hair-sacs and sebaceous glands, has been shown. (Fig. 134.)

6. *New* formations of sebaceous glands have been found in an ovarian cyst in connection with hair. Indeed, they may probably occur in any part containing new formations of hair-sacs. A new development of sebaceous glands occurs in cicatrices in the skin, of some years' standing. (*Von Bärensprung*).

IV. Of the pathological conditions of the *sweat-glands* but little is known. In *elephantiasis* Græcorum they become hypertrophied; while they are atrophied in case of corns, and the sweat-duct disappears in the outer layer of the cuticle.

New formations of sweat-ducts occur in connection with those of hair and sebaceous glands, as in ovarian cysts; and in Mohr's case of a large cavity in the lung lined by a membrane in all its elements like the skin (with a subcutaneous areolar tissue under it), and on which hairs, sebaceous follicles, and papillæ were developed.

II. The Mucous Membranes.

Mucous membranes line the cavities opening externally, and, like the skin, consist of a corium, a basement-membrane, and an epithe

lium. The basement-membrane is like that of the skin. The corium is also composed of collagenous and elastic tissue, contains vessels, nerves, smooth muscular fibres, glands, papillæ, and other peculiar processes (villi). Beneath the corium there is, in most parts, a layer of submucous areolar tissue. The development and regeneration of mucous membranes also resemble those of the skin so nearly as not to demand a separate consideration.

The mucous membranes present marked differences in structure in different situations. They will, therefore, be described separately, in connection with the other structural elements of the organs, respectively, of which they form a part, viz:—

1. In the Alimentary Canal.
2. " Urinary Apparatus.
3. " Genital Apparatus.
4. " Air-passages.

Functions of the Mucous Membranes.

All the mucous membranes are, 1, *protective* of the passages lined by them; 2, they *secrete* mucus, of different kinds in different parts (p. 195); 3, they absorb also in certain parts; *e. g.* the villi of the small intestine, &c.; 4, they constitute an *aerating* surface to some extent (*e. g.* in air-passages); 5, some portions of these membranes manifest the sense of touch also (lips, genital organs, &c.).

Pathological States of the Mucous Membranes.

1. *Atrophy* of mucous membrane is rare (*Engel*); but is seen in the alimentary canal of the aged. Here the gastric mucous membrane becomes less plicated and smoother; while the peptic glands are diminished in number. In the duodenum, Brunner's glands become atrophied, and the villi of the small intestine become clouded from the apex towards the base, pigmented, lessened in size (especially transversely), and even in number also. The valvulæ conniventes are also less prominent, and the Peyerian and solitary glands collapse; their situation being indicated merely by a pigmented border.

2. Inflammatory exudations on the mucous membranes (except the mouth, œsophagus, vagina, and palpebræ), generally at once detach the epithelium; and, therefore, no vesicles form upon them, except in the parts mentioned. Thus, the exudation may be at once examined. It is also not so generally circumscribed, as in the case of the skin; and the submucous tissue and the glands it contains are very frequently involved. Hence the membrane becomes thickened and swollen. Extravasation of blood is also more liable

to occur from the weaker vessels; and hence ecchymoses are very common. The *polypi*, so called, of the stomach, are merely groups of peptic glands, rendered prominent by an exudation deposited around them.

3. The thinness of the corium of the mucous membrane accounts for its tendency to losses of substance by ulceration; the bottoms of which are covered by various products (exudation). The latter sometimes rise like a plug above the level of the membrane (as in typhoid fever). Vegetable parasites are also frequently developed in exudations on mucous membranes.

III. The Serous Membranes.

The true serous membranes are the peritoneum, the pleura, the tunica vaginalis testis, and the pericardium. All these have a simple scaly epithelium (p. 238, and Fig. 140), generally a thinner corium than the mucous membrane, and which presents neither papillæ nor glands; and constitute closed cavities, moistened by the secretion of their epithelial cells, and an accompanying transudation (pp. 180—1). They will be described in connection with the parts and organs into the structure of which they respectively enter. The tunica vaginalis is originally an offset from the peritoneum.

The *synovial* membranes are often called serous membranes; as are also the bursæ mucosæ and the vaginal sheaths of tendons. It has, however, been shown that histologically they are not such, since they do not form closed cavities (p. 344, and Fig. 233). The arachnoid also has but a single layer (p. 469) and the ependyma of the ventricles has not everywhere a corium (p. 469). The arachnoid, however, normally presents villi; which, becoming enlarged, constitute the Pacchionian bodies.

Function of Serous Membranes.

The serous membranes proper, merely subserve the mechanical purpose of facilitating motion of one part on another, and diminishing friction; both by the smoothness of their surface and the secretion they produce (p. 181).

An abnormal accumulation of the natural secretion of the serous membranes in their cavities, constitutes the various forms of dropsy; *e. g.* in the pleural cavity, *hydrothorax;* in the peritoneal, *ascites;* in the tunica vaginalis, *hydrocele;* and in the pericardium, *hydrops pericardii.* An exudation upon the pleura becoming degenerated into pus, constitutes *empyema.* The conversion of exudations into new formations is explained under the next head.

IV. False Membranes.

This expression is a very objectionable one; since it may either mean merely a coagulated exudation, spread upon a surface, like a membrane, or the same exudation after it has become organized. *E. g.* the merely fibrillated and never vascular exudation of croup, is termed a false membrane, as well as the highly vascular membraniform formation, so common on the surface of the pleura in consequence of inflammation of this membrane. The former should be called merely a *coagulated exudation;* while the latter may be termed a *false membrane*, if we intend by this expression to indicate the fact shown by the microscope, that these formations are *not* (histologically) membranes, though they sometimes, from their form, appear to the unaided eye to be such.

False membranes are, therefore (if the term is to be retained), more or less *organized exudations of plasma*, and are developed especially upon serous membranes (p. 188, 2). They, however, present all grades of development and vascularity, according to the time elapsing since the occurrence of exudation. When fully formed, they consist of a layer of imperfectly developed areolar tissue, containing a vascular network, and sometimes even nerves also, and lymphatics. Consequently, they are really mere *new formations of areolar tissue.*

False membranes being a new formation are prone to involution, and ultimately may entirely disappear. Fatty degeneration in them is very common. They are also frequently the seat of pathological epigeneses, especially of tubercle.

The *bands* and *adhesions* so frequently resulting from pleuritis and peritonitis, are histologically identical with false membranes; being also new formations of areolar tissue.

New membranes are sometimes formed to cover the surface of permanent adventitious cavities; *e. g.* the membrane lining cavities in the lung, formed by the removal of a mass of tuberculous deposit, &c.

A new formation of *epithelium* occurs in many pathological cysts; of the internal surface of which the new formation constitutes the lining.

CHAPTER XII.

THE VASCULAR SYSTEM.

THE vascular system consists of the heart, the bloodvessels, and the lymphatic vessels.

I. THE HEART.

The *heart* is a thick muscular organ, divided into four cavities, covered externally by a serous membrane—the *pericardium*—and lined internally by the *endocardium*, a continuation of the inner tunic of the large vessels.

The *pericardium* presents two layers; the outer (sero-fibrous layer) being much the thicker, and fibrous in its external portion. The inner layer, much thinner, is very intimately attached to the muscular fibres of the heart, except over the sulci containing the vessels and nerves, where it is separated by common adipose tissue. Sometimes, however, the fatty sub-serous layer extends almost over the whole heart. The scaly epithelium of the pericardium contains one or two layers of cells, and presents no peculiarities. But few *lymphatics* exist on the outer layer, while they are more abundant in the muscular substance of the heart. Subdivisions of the diaphragmatic and recurrent laryngeal nerves have been demonstrated by Luschka in the outer layer.

The *muscular fibres* of the heart are of the transversely striated kind, but they are about one-third smaller than those of the voluntary muscles ($\frac{1}{3000}$ to $\frac{1}{1200}$ of an inch), and are often more distinctly striated in the longitudinal than the transverse direction. They also almost always contain minute fatty granules, arranged in a series in their axes. Their *myolemma* is very delicate, and often not to be seen at all. The most striking peculiarity is, however, the intimate union of the fibres; they being everywhere separated by a very scanty connective tissue, and never forming manifestly distinct fasciculi. Besides, anastomoses of the fibres exist (Fig. 330), and also true divisions.

For the complex *course* of the fibres of the heart, we refer to the

works on anatomy. The muscular structures of the auricles and ventricles are completely distinct; both, however, originating chiefly from the *ostea venosa* of the ventricles, where the so-called fibro-cartilaginous rings are situated.

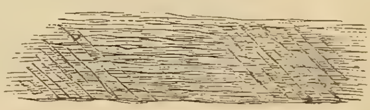
Fig. 330.

Anastomosing muscular fibres from the human heart. (*Kölliker.*)

The *endocardium* is a whitish membrane covering all the internal surface of the heart, as well as the columnæ carneæ, the chordæ tendineæ, and the valves. It is thickest ($\frac{1}{48}$ of an inch) in the left auricle, and thinnest in the ventricles. It consists of two layers: 1*st*, a scaly epithelium of one or two layers of clear, flattened, nucleated cells, resting, without any apparent basement-membrane, upon the surface of, 2*dly*, the elastic layer. The latter, determining the varying thickness of the endocardium, has its superficial layer made up of very fine, longitudinal, elastic fibres, and the remainder of areolar tissue, with scattered nuclei. In the auricles, this membrane becomes almost entirely an elastic membrane, and is therefore quite yellow. It is very delicate over the chordæ tendineæ. Under the endocardium lies a very delicate stratum of areolar tissue, attaching it to the muscular fibres. The *chordæ tendineæ* are composed of collagenous tissue, like the tendons.

The *auriculo-ventricular valves* present three layers—a middle one of areolar tissue with numerous elastic networks, and two lamellæ of the endocardium. Towards their free borders, these three are condensed, as it were, into a single layer of areolar tissue and elastic networks, over which the epithelium is continued. The *semilunar valves* present the same condition as the free borders of the preceding. (Fig. 331.)

Fig. 331.



Elastic layer of a semilunar valve, beneath the endocardium.

The *vessels* of the heart present only the following peculiarities. The capillaries often encompass several of the fibres in common, on account of the small size of the latter. The endocardium has very few vessels, while they are plentifully distributed to the subjacent layer of areolar tissue. A few vessels are seen in the auriculo-ventricular valves, but never exist in the semilunar. *Lymphatics*

exist on the muscular substance of the heart beneath the pericardium; but whether they are present in its substance and in the pericardium, is not determined. The *nerves* (from the pneumogastric and sympathetic) contain, except the largest, only pale and fine fibres. Ganglia also exist in the substance of the heart. Dr. Lee, of London, however, mistook for ganglia mere thickenings of the perineuria. (*Kölliker.*) How the nerve-fibres terminate, is unknown.

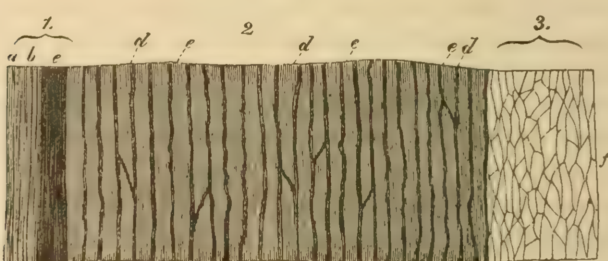
II. The Bloodvessels.

The bloodvessels are divided into the arteries, the capillaries, and the veins.

A. *The Arteries.*

The *arteries*[1] have three tunics, the external (*adventitia*), the middle (*media*), and the internal (*intima*). (Fig. 332.) Each of these may,

Fig. 332.



Transverse section of the aorta below the superior mesenteric artery. 1. Inner tunic. 2. Middle tunic. 3. External tunic (adventitia). *a.* Epithelium. *b.* Striped lamellæ. *c.* Elastic membrane of the inner coat. *d.* Elastic lamellæ of the middle tunic. *e* Its muscular fibres and connective tissue. *f.* Elastic networks of the external tunic. From man, treated with acetic acid.—Magnified 30 diameters. (*Kölliker.*)

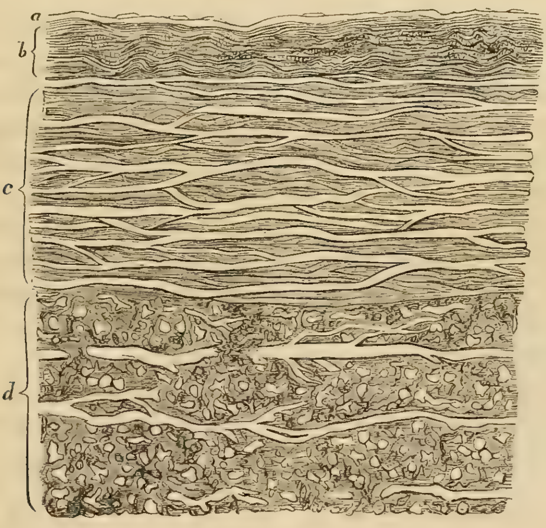
however, be subdivided, as will be seen. In general, the external coat consists of areolar tissue; the middle of elastic tissue, with more or less smooth muscular fibres admixed; and the internal of an elastic network (fenestrated layer), supporting an epithelium.

1. The *external coat* of the (1*st*) *larger* arteries (above 2 or 3 lines in diameter) is both relatively and absolutely thinner than in the smaller—being $\frac{1}{600}$ to $\frac{1}{300}$ of a line—and presents the same structure as in the smaller arteries on the whole; it being composed of

[1] Meaning "air-holders" (p. 405, note); since the ancient anatomists observed that they usually contained air after death.

areolar tissue, with an elastic inner layer. In the (*2dly*) medium-sized arteries ($\frac{4}{5}$ of a line to 2 or 3 lines) this coat is thicker than the middle coat, being $\frac{1}{240}$ to $\frac{1}{75}$ of an inch thick. It has an inner portion, in the form of a laminated elastic membrane, in the largest arteries of this class (brachial, femoral, &c.). The external portions of the external coat also abound in elastic fibres, sometimes presenting a laminated aspect. *3dly.* In the *small* arteries (less than $\frac{4}{5}$ of a line in diameter), the external tunic is merely a layer of areolar tissue, as thick or thicker than the *tunica media.* In arteries $\frac{1}{10}$ of a line or less in diameter, however, the outer coat contains no elastic fibres, but only collagenous tissue and elongated nuclei; and which, though still nucleated, at length, towards the capillaries, become homogeneous, then a thin simple membrane, and finally, in vessels under $\frac{1}{1750}$ of an inch, disappear altogether.

Fig. 333.



Section of the aorta of the ox, showing the arrangement of the two layers of the longitudinal fibrous tunic, and of the circular fibrous tunic. *a* and *b*, the inner coat: *a*, the epithelial layer; *b*, the internal portion of the longitudinal fibrous layer (fenestrated membrane, *Henle*). *c* and *d*, the middle coat; *c*, the external coarse stratum of the longitudinal fibrous layer; *d*, a small portion of the circular fibrous tunic; most of the fibres are cut across, but a few which take an oblique course, are seen in their whole length, and their penniform branching is slightly indicated. (Longitudinal section.)

2. The *middle coat of large arteries* (Fig. 333) consists of plates of elastic tissue, of collagenous tissue, fine elastic networks, and smooth muscular fibres; the last constituting only one-fourth to one-third

of the whole tunic, and being in a merely embryonic state of development. They therefore probably manifest but little contractile power. Its innermost stratum, the *annular fibrous* layer, contains the peculiar elastic membranes or plates, of $\frac{1}{12000}$ to $\frac{1}{10000}$ of an inch, and 50 to 60 in number, regularly alternating, at distances of $\frac{1}{4000}$ to $\frac{1}{500}$ of an inch, with transverse layers of smooth muscular fibres, pervaded by areolar tissue. These plates are, however, not mere concentric tubes, but are connected with each other, and with the firm elastic network pervading the muscular tissue. (Fig. 333.) In the middle coat of the *medium-sized* arteries the elastic plates just described are absent, and the smooth muscular fibres are far more abundant; though there is here and there a disposition to the formation of elastic layers, alternating with the muscular. Its muscular fibres, therefore, preponderate, and doubtless manifest a considerable degree of contractile force. It is thinner than the external coat.

The *small* arteries have their middle coat composed exclusively of smooth muscular fibres; and it is stronger or weaker, according to the size of the vessel, down to $\frac{1}{400}$ of an inch. In vessels of $\frac{1}{120}$ to $\frac{1}{300}$ of an inch, they are still united into lamellæ presenting two or three layers, and a thickness of $\frac{1}{2400}$ to $\frac{1}{1500}$ of an inch, constituting the *annular fibrous layer* next the inner coat. In smaller vessels it has but a single layer of minute fibres, the latter becoming shorter and shorter towards the capillaries. In arteries of $\frac{1}{1000}$ of an inch, embryonic forms of smooth fibres still constitute a connected lamina (Fig. 337, B), but afterwards they are gradually separated from each other, and become wholly lost.

3. The *inner tunic* of all the arteries consists of two layers—the elastic and the epithelial. 1. The *elastic* (*fenestrated*, Henle) layer is merely a network of longitudinal elastic fibres, resembling the

Fig. 334.

Fig. 335.

Fig. 334. Internal or finely fibrous portion of the longitudinal fibrous (fenestrated) layer of the aorta of the horse. (Magnified 200 diameters.)

Fig. 335. External or coarsely fibrous portion of the longitudinal fibrous layer of the aorta of the horse. (Magnified 200 diameters.)

elastic lamellæ of the middle coat of the large arteries. The elongated fissures between its fibres produce its fenestrated appearance. (Fig. 334.) In the largest arteries this is reinforced externally by a coarsely fibrous layer of elastic tissue, shown by Fig. 335.

1. In the *large* arteries the *fenestrated* layer is thickened internally by one or several clear layers—the *striped lamellæ* (*Henle*)[1]—appearing, when nucleated, like coalesced epithelial cells; and when not so, homogeneous, like pale elastic membranes. In the axillary and popliteal arteries, smooth muscular fibres have also been found in this layer. (Fig. 244.) In the *medium-sized* and the *small* arteries, the fenestrated layer, or elastic stratum, is $\frac{1}{12000}$ of an inch or more thick, and smoothly stretched beneath the epithelium during life. In collapsed arteries it presents a number of strong folds, and frequently also fine transverse rugæ. It may be traced down into vessels only $\frac{1}{440}$ of an inch in diameter; but cannot be regarded as fully developed in those less than $\frac{1}{200}$ of an inch. 2. The *epithelial* layer of the *tunica intima* consists of a single layer of flattened nucleated cells. These in the *large* arteries are usually shorter than in the smaller vessels, though still fusiform, and $\frac{1}{2000}$ to $\frac{1}{1200}$ of an inch long. (Fig. 336.) In the *medium-sized* and *small* arteries, they are fusiform, pale, with long oval nuclei, and readily separated in connection, in fragments, or in perfect tubes. The epithelium may be traced in vessels of only $\frac{1}{1200}$ or even $\frac{1}{1714}$ of an inch in diameter. Here, however, the cells cannot be isolated, and its presence can be recognized by its closely placed elliptical nuclei alone.

Fig. 336.

Epithelial cells from the aorta of an ox. (Magnified 400 diameters.)

All the arteries (and the veins), above $\frac{1}{24}$ of an inch in diameter, have *nutritive vessels* (*vasa vasorum*), derived from minute contiguous arteries, forming a rich capillary network in the external tunic, and which extend into the outer portion of the middle coat of the large vessels, but not to its inner portion, nor to the inner coat at all. *Nerves* also, both sympathetic and spinal, are distributed to many arteries, but often only accompany them.

[1] In the large vessels the striped lamellæ are sometimes not covered by, but are continuous with, the epithelium.

When they enter the artery they cannot be traced beyond the outer coat. Many arteries are, however, without nerves; *e. g.* those of the cerebral and spinal substance, of the choroid plexus and the placenta, as well as many arteries of muscles, glands, and membranes. Of the *veins*, it is only in the larger that a few fine nerves can be demonstrated, *e. g.* the sinuses of the dura mater, the vertebral canal, the venæ cavæ, and the jugular, iliac, femoral, and hepatic veins. These also are both spinal and sympathetic. Luschka thinks they terminate in the inner coat—a point not yet decided.

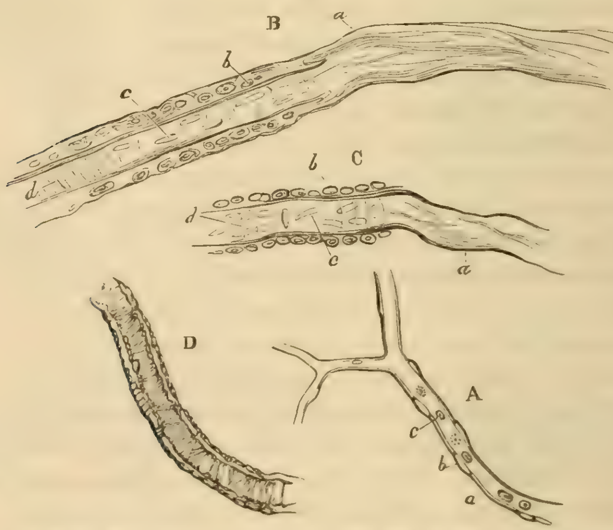
B. *The Capillaries.*

The arteries terminate in the capillaries—vessels always intervening between the former and the veins; except in case of the corpora cavernosa penis, and of the placenta. (*Kölliker.*)

The capillaries are everywhere composed of a single layer of simple membrane with nuclei; the structural transitions of the small arteries into these vessels being wholly imperceptible. (Fig. 337, B.)

On minute examination, the structureless membrane is sometimes transparent, and with a simple contour; at others, thicker ($\frac{1}{15000}$

Fig. 337.



A. A capillary vessel from the gray matter of the human brain; *a*, wall, of simple membrane; *b*, nucleus of the wall; *c*, red blood-corpuscles. B, C. Different appearances of small arteries and veins of the human pia-mater; *a*, *a*, simple membrane; *b*, *b*, circular fibres; *c*, *c*, oval nuclei of the internal epithelium here about to cease; *d*, *d*, transverse indications of the circular fibres. D. Terminal artery from the mesentery of a rabbit. (Magnified 200 diameters.)

to $\frac{1}{12000}$ of an inch), and bordered by a double line. It corresponds chemically with the myolemma of the striated muscular fibres; is perfectly smooth on both sides, and tolerably resistant and elastic, though probably not contractile. (*Kölliker.*) The *nuclei* are elongated, $\frac{1}{4000}$ to $\frac{1}{3000}$ of an inch in diameter, and usually alternate on opposite sides of the vessel, though rarely in contact with each other. When the capillary wall is thick they are lodged in its substance, though sometimes projecting externally; when thinner, they are situated on its inner side. (Fig. 337.) Their diameter varies from $\frac{1}{6000}$ to $\frac{1}{2000}$ of an inch.

The union of the capillaries constitutes a *capillary plexus*, already described, in connection with the different tissues and organs. As the histological *elements* of the various tissues are not themselves penetrated by capillaries, but the latter are merely distributed among the former, the capillary plexus of each tissue and organ will assume a form more or less peculiar. Generally, indeed, a tissue or organ may be at once recognized by its capillary network alone. It is closest in the secreting organs (especially the liver, lungs, and kidneys) (Figs. 406, 375); next in the skin, and mucous membranes (Figs. 322 and 353); and is much wider in organs receiving blood only for their own nutrition, as the muscles, nerves, organs of sense, serous membranes, tendons, and bones. (Figs. 266, 176, &c.) The muscles and the gray nerve-substance are, however, more abundantly supplied than the other parts just mentioned. Their diameter also varies directly with the closeness of the plexus; it being $\frac{1}{3000}$ to $\frac{1}{2000}$ of an inch in the glands, $\frac{1}{4000}$ to $\frac{1}{2400}$ in the skin and mucous membranes, and thinnest and smallest ($\frac{1}{6000}$ to $\frac{1}{4000}$ of an inch) in the nerves, muscles, retina, and the patches of Peyer. In the compact bone structure, however, though no longer having, in all respects, the structure of capillaries, they attain to the diameter of $\frac{1}{1500}$ to $\frac{1}{1200}$ of an inch (p. 337, 2).

On tracing the capillaries towards the arteries, the nuclei become more closely placed, and a structureless *tunica adventitia*, and solitary muscular cells, appear externally; and becoming $\frac{1}{1714}$ of an inch in diameter, they exhibit the aspect of the finest arteries. Afterwards the nuclei seem to be replaced by epithelium, and the membrane of the capillary either ceases, or is continuous with the fenestrated layer of the artery. (Fig. 337, B.)

The capillaries merge in the opposite direction into the veins by less characteristic changes. On this side an external nucleated

layer is first added to the capillary membrane, and which gradually combines with the latter, while the nuclei of the capillaries become more closely approximated. In vessels of $\frac{1}{1200}$ of an inch, they have become so numerous as clearly to represent the epithelium, and now the external layer has received also the addition of a nucleated lamina, the *tunica adventitia*, and the vessel has become a *vein*. (Fig. 337, c.)

The older anatomists have also assumed the existence of still finer vessels than the capillaries, never admitting the blood-corpuscles, called *vasa serosa;* and recently Hyrtl has admitted their existence in the cornea. If any such vessels exist in the cornea, they must be regarded as atrophied capillaries; the latter having formed an abundant plexus in the fœtus. It cannot be admitted that such vessels exist in the adult in any other part, at any rate (p. 281). The finest capillaries above-mentioned have a less diameter than the smallest blood-corpuscles; but the latter easily adapt themselves by their extensibility and elasticity to traverse the former.

c. *The Veins.*

The *veins* also present three tunics—the *adventitia* (external), the *media*, and the *intima;* and may also be divided into the small, the medium-sized, and the large. Their walls are always thinner than those of the arteries, there being less of both the muscular and the elastic element. The external coat is usually the thickest of the three; its relative and absolute thickness usually increasing with the size of the vessel. The inner coat is often not thicker in large veins than in those of medium size.

1. The *smallest veins* may be said to consist of a nucleated indistinctly fibrous or homogeneous areolar tissue, lined by a scaly epithelium. A *muscular membrane*, and generally a layer of annular fibres are first seen in veins above $\frac{1}{600}$ of an inch in diameter; the contractile cells being at first oval, placed transversely (Fig. 337, c), and widely apart, but which afterwards become longer and more numerous; and, finally, in vessels of $\frac{1}{1200}$ up to $\frac{1}{120}$ of an inch, constituting a continuous layer, but always less developed than the middle coat of the small arteries. Afterwards, elastic networks gradually make their appearance in this muscular layer, and in the external coat; the muscular layers also multiplying, and admitting areolar tissue among their elements.

2. The *medium-sized* veins (1 to 3 lines in diameter) have an *external* tunic almost always thicker than the middle coat, often twice as thick, though rarely as strong. It is composed of areolar tissue, except in some visceral veins whose trunks contain longitudinal muscular fibres, and into whose branches also the muscular elements extend for some distance.—The *middle* coat has a considerable development of the *annular fibrous layer*, of a yellowish-red color, as in the arteries. It, however, is never more than $\frac{1}{200}$ to $\frac{1}{171}$ of an inch thick. Unlike that of the arteries, it consists of longitudinal as well as transverse layers. (Fig. 338.)

Fig. 338.

Transverse section of the vena saphena magna at the malleolus. *a.* Striped lamellæ and epithelium of the tunica intima. *b.* Its elastic membrane. *c.* Longitudinal internal connective-tissue layer of the tunica media, with elastic fibres. *d.* Transverse muscular layer. *e.* Longitudinal elastic network disposed in a laminated manner. *f.* Tunica adventitia.—Magnified 30 diameters. (*Kölliker.*)

The latter are composed of undeveloped areolar tissue and a large amount of smooth muscular fibres. In the popliteal, saphena major and minor, and the profunda femoris vein, there is a transverse layer of muscular fibres with areolar tissue, immediately in contact with the *tunica intima*, external to which is a regular alternation of longitudinal elastic membranes and transverse muscular fibres; so that the middle coat presents a laminated aspect somewhat like that of the largest arteries. There are from five to ten of these elastic laminæ; their interspaces being from $\frac{1}{3000}$ to $\frac{1}{1200}$ of an inch.—The *inner* coat of the medium-sized veins is $\frac{1}{1200}$ to $\frac{1}{300}$ of an inch thick. Where it is thinnest, it consists of an elastic longitudinal membrane, corresponding to the fenestrated membrane of the arteries, and a striated nucleated lamella within it, and an epithelium with shorter, though elongated cells. When the tunica intima is thicker, the striated lamellæ are multiplied, and one or several additional networks of fine elastic fibres appear on the inner surface of the latter, forming the limitary portion of the inner coat. Muscular fibres also have been seen in the inner coat of the veins of the gravid uterus, in the saphena major, and the popliteal vein. (*Kölliker.*)

3. In the *largest veins* the *external* coat is almost invariably nearly twice as thick as the middle, and sometimes five times as thick, and also contains a considerable amount of longitudinal smooth muscular fibres. (Fig. 243.) These are very distinct in the hepatic portion of the inferior vena cava (*Bernard*), constituting a network pervading

the inner half, or two-thirds of the external coat, which rests upon the tunica intima directly, and may become $\frac{1}{55}$ of an inch thick. Kölliker found these longitudinal bundles extending through the entire thickness of the external coat in the renal veins and the vena portæ; and very well developed also in the trunks of the hepatic veins, the remaining portions of the vena cavæ, and to the splenic, superior mesenteric, and external iliac veins. All the large veins opening into the heart, are furnished for a short distance also with an external annular layer of *striated muscular fibres*, like those of the heart itself, and some of them also presenting anastomoses. They extend in the superior vena cavæ to the subclavian vein; and may be found in the main branches of the pulmonary veins. (*Räuschel.*)

The *tunica media* of the large veins is sparingly developed, and especially its muscular elements, which are, however, often abundant in the external coat, as has just been stated. It is usually $\frac{1}{600}$ to $\frac{1}{300}$ of an inch thick; but may be $\frac{1}{240}$ to $\frac{1}{100}$ of an inch (at the orifices of the hepatic veins), or may be wholly wanting; as in the greater part of the vena cava in the liver, and the trunks of the hepatic veins. Its longitudinal elastic networks are intimately connected together, and less distinctly laminated than in the medium-sized veins, or not at all so. The transverse muscular fibres are also scanty and less distinct; being most developed in the splenic vein and vena portæ. The *tunica intima* is usually $\frac{1}{1200}$ of an inch, when it presents the same conditions as in the medium-sized veins. Rarely, as in the vena cava inferior, the trunk of the hepatic, and in the vena innominata, it is $\frac{1}{600}$ to $\frac{1}{400}$ of an inch thick; this increase of thickness being due to *striped lamellæ* with nuclei, and fine elastic longitudinal networks, and never to lamellæ composed of muscular fibres.

In the veins of the gravid uterus the *muscular* element is *exclusively developed;* it existing in all three of their tunics. It is entirely *wanting*, 1, in the veins of the maternal portion of the placenta; 2, in most of the veins of the cerebral substance and of the pia mater; 3, in the sinuses of the dura mater, and the veins of Breschet in the bones (which have merely a layer of collagenous tissue external to a scaly epithelium); 4, in the sinuses of the corpora cavernosa; and 5, in the veins of the retina.

The *valves* of the veins are projections of the middle and internal tunics. Muscular fibres have been found by Wahlgren in the larger valves.

III. The Lymphatic Vessels and Glands.

The lymphatic vessels correspond so closely in structure with the small veins, as to require but a brief description.

The finest (*capillary*) lymphatics have been seen with certainty only in the small intestine, the mucous membrane of the trachea, and the tail of the tadpole. They have a wall of simple membrane without distinct nuclei, and a diameter of $\frac{1}{4000}$ to $\frac{1}{1200}$ of an inch. (Fig. 339.) How these are changed into the *larger lymphatic* vessels (Fig. 341, B and C), is unknown. Of the latter, the smallest

Fig. 339.

Capillary lymphatic from the tail of the tadpole. *a.* Simple membrane. *b.* Process formed by it. *c.* Remains of the contents of the cell forming these vessels, in which nuclei are concealed. *d.* Granules, forming lymph-corpuscles. *e.* Cœcal termination of the vessels. *f.* One of the terminations, still pretty distinctly recognizable as a formative cell. *g.* Isolated formative cells about to join with the actual vessels. (*Kölliker.*)

are $\frac{1}{120}$ to $\frac{1}{72}$ of an inch, the larger 1 to $1\frac{1}{2}$ lines. The last present 3 coats. The *external* coat contains longitudinal smooth muscular fasciculi. The *middle* coat is composed of transverse muscular, and fine elastic fibres. The *tunica intima* consists of a single, and rarely double, elastic reticulated membrane, and an epithelium of elongated, though still rather short, cells. (Fig. 142.)

The *thoracic duct* has striped lamellæ between the epithelium and the elastic reticulated membrane, though the whole inner coat scarcely measures $\frac{1}{2000}$ to $\frac{1}{1200}$ of an inch. The middle coat ($\frac{1}{480}$ of an inch thick) contains a transverse muscular layer and areolar

tissue. (Fig. 340.) The outer coat is composed of areolar tissue and longitudinal fasciculi of smooth muscular fibres.

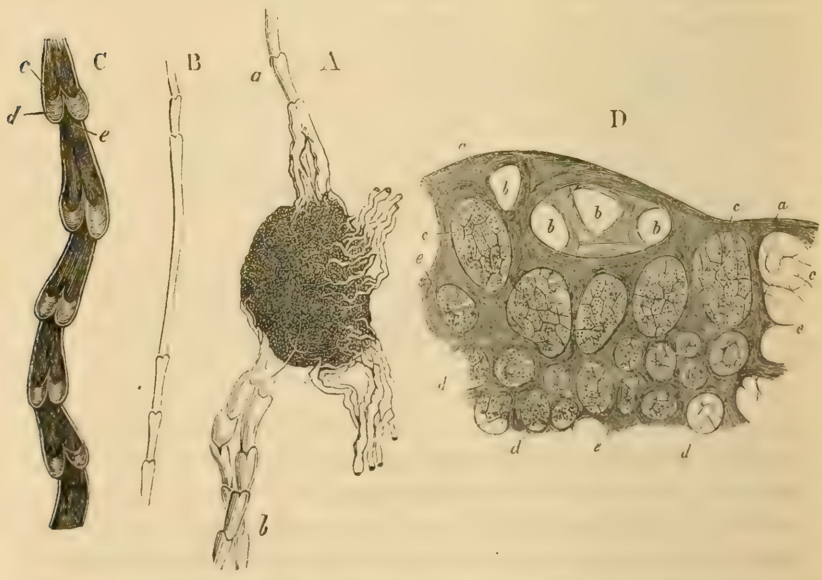
Fig. 340.

Transverse section of the human thoracic duct. *a*. Epithelium, striped lamellæ, and elastic inner membrane. *b*. Longitudinal connective-tissue of the tunica media. *c*. Transverse muscles of the same tunic. *d*. Tunica adventitia, with *e*, the longitudinal muscles. — Magnified 30 diameters. (*Kölliker.*)

The *valves* of the duct, and of the lymphatics generally, correspond with those of the veins. The *vessels* present the same conditions in the duct, as those of the veins. No *nerves* have yet been found in the lymphatics.

The *lymphatic glands* present a thin, fine sheath of areolar tissue inclosing a soft whitish-red parenchyma, in which a fibrous portion, a soft pulp, and bloodvessels are seen. 1. The fibrous portion is areolar tissue proceeding from the sheath, and taking the form of many lamellæ; it constitutes an elegant areolated structure

Fig. 341.



A. One of the inguinal lymphatic glands injected with mercury; *a*, afferent lymphatic vessels from the lower extremity; *b*, efferent vessel—others are also seen. B. One of the superficial lymphatic trunks of the thigh. C. One of the femoral lymphatic trunks laid open longitudinally to display the valves within it; *c*, sinus between the valves and the wall of the vessel. *d*. Surface of one valve directed towards the opposite; *e*, semicircular attached margin of the valve. D. Section of lymphatic gland, showing *a a*, the fibrous tissue which forms its exterior; *b b*, superficial vasa afferentia; *c c*, larger alveoli near the surface; *d d*, smaller alveoli of the interior; *e e*, fibrous walls of the alveoli. (*After Mascagni.*)

pervading the entire gland, all of whose rounded spaces, $\frac{1}{72}$ to $\frac{1}{36}$ of an inch wide, communicate freely. 2. The grayish-white alkaline pulp filling them, agrees, in almost all respects, with that in the follicles of Peyer. (Fig. 360). 3. Vessels also enter these spaces and form a fine vascular network as in the follicles just mentioned. (Fig. 341, A.)

The lymphatic glands are, therefore, not mere convolutions of the lymphatic vessels; but distinct and independent structures, in the areolæ (*alveoli*, *Kölliker*) of which the *vasa afferentia* terminate, and the *efferentia* commence. The cells contained in the pulp seem identical with the lymph- (cytoid) corpuscles of the blood; and a portion of the latter may, perhaps, be developed here. The *vasa afferentia* lose their muscular layer as they enter the gland, and enter the *alveoli* with only a layer of areolar tissue and an epithelium. Nervous filaments composed of fine fibres enter the glands with the vessels, and disappear in their interior.

The most common *degeneration* of the lymphatic *glands* is produced by the extravasation of blood into the alveoli, leading to deposits of quite dark pigmentary matter (as in the bronchial glands). The sheaths, or internal septa, are also liable to become thickened, and fatty deposits to occur in the bloodvessels. Hypertrophy of all their elements may also occur, and tuberculous and cancerous deposits.

Functions of the Vascular System.

For the precise *rôle* of each part of the blood-vascular system in securing the circulation of the blood, and for the action of the lymphatics, reference must be had to the works on physiology. The blood and lymph (and chyle) have already been described at length (p. 147–79).

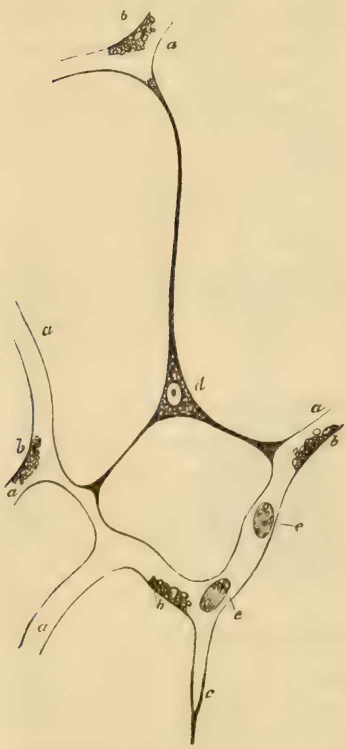
Development of the Vascular System.

1. The rudiments of the heart, arteries, and veins are alike solid tracts of cells, of greater or less thickness; which, by a liquefaction internally, and a transformation of the central cells into blood-corpuscles, become *cavities* and continuous passages for the blood. The heart manifests contractions while still in the form of a cellular tube; and subsequently the cells occupying the walls elongate into the muscular and other fibres. At the same time, the vessels become thicker, and increase in circumference, at first by an augmentation of the number of the cells; afterwards chiefly, if not solely,

by their growth in length and thickness. In the fifth month of fœtal life, all the larger and medium-sized vessels are formed with their coats and tissues, and no vestige of the formative cells remains. The tissues are, however, still incomplete, the muscular fibres being short and delicate, and there being only layers of slightly coalescent fusiform cells, instead of the elastic membranes subsequently to appear.

2. The *capillaries* are developed in an entirely different manner from the preceding, since they are formed by the coalescence of single cells. These are first arranged in a line, then the contiguous cell-walls are absorbed, with their contents, but not their nuclei, which still appear, therefore, in the wall of the capillary vessel. Delicate pointed processes then project from the walls of these little vessels, which rapidly elongate, and coalesce with similar processes of stellate cells dispersed in the surrounding tissue. The other processes of these stellate cells also unite, and thus a network of stellate cells, continuous with the already formed capillaries, is produced. The passages in this network are at first very minute and irregular, and do not admit the blood-corpuscles; but they rapidly enlarge, and become true capillaries. (Fig. 342.) New connections are also frequently formed between already pervious capillaries, by the direct meeting of prolongations from them, and by the mutual connection of formative cells lodged in their interstices.

Fig. 342.



Formation of capillaries in tail of tadpole. *a, a*. Capillaries permeable to blood. *b, b*. Fat-granules attached to the walls of the vessels, and concealing the nuclei. *c*. Hollow prolongation of a capillary ending in a point. *d*. A branching cell with nucleus and fat-granules, communicating by three branches with capillaries already formed. *e*. Blood-corpuscles still containing granules of fat.

3. The *capillary lymphatics* exhibit essentially the mode of development just described; except that anastomoses are rare in them, and

its course is limited to the mutual apposition of fusiform cells, or of those furnished with three principal processes.

Pathological Conditions and New Formations of the Vessels.

The larger *arteries* are liable—1. To *atheromatous deposits* (p. 312); these occurring in the annular fibrous layer (*i. e.* next external to the *fenestrated*). (Figs. 198 and 199.) It appears to be due to imperfect nutrition by the vasa vasorum (*Wedl*), and is therefore one form of atrophy. The arterial wall becomes weaker in proportion to the accumulation of the fat; and, becoming dilated, an *aneurism* is very often produced. 2. By the collapse of their walls (as by pressure, ligature, &c.), the arteries become *transformed* into ligamentous cords, and finally into mere fibrils of collagenous tissue, covered with a finely granular substance.

3. The *veins* undergo essentially the same changes in atrophy, and *varix* is the consequence. The deposit is usually a finely granular pigment-substance. This change also occurs in their valves.

Fig. 343.

Fatty degeneration of minute arteries and capillaries of the brain. in white softening. Numerous minute oil-globules are seen aggregated along their walls.

4. The *capillaries* are liable to a fatty degeneration of their walls; fatty granules and minute oil-drops being deposited in them, especially around the nuclei. (Fig. 343.) The minute arteries also undergo a similar change, especially in the brain of apoplectic persons; and which leads to rupture, and the hemorrhage in which the apoplexy consists.

5. Pathological *new formations of vessels* occur in two ways: 1*st*, by extension from pre-existing vessels; and, 2*dly*, by independent development in exudations undergoing organization. In the latter case, the processes of various stellate cells meet, the dissepiments are absorbed, and a network of vessels is produced, of unequal dimensions, since the processes are far slenderer than the bodies of the cells. Finally, however, the diameter becomes uniform throughout the plexus, and is usually greater than that of the capillaries of normal tissue. Subsequently, also, blood-corpuscles are developed in the plasma contained in the new-formed vessels; but which cannot pass into the general circulation till a communication is established with it by them.

CHAPTER XIII.

STRUCTURE OF THE ALIMENTARY CANAL AND ITS APPENDAGES.

THE alimentary canal is a tube commencing with the mouth, or oral cavity, and ending at the anus. It is divided into—1*st*, the supra-diaphragmatic portion, consisting of the oral cavity, the pharynx, and the œsophagus; and, 2*dly*, the infra-diaphragmatic portion, including the stomach, small intestine, and large intestine. Underneath the mucous membrane is, in most parts, a layer of submucous areolar tissue; and externally to this, two layers of smooth muscular fibres; except in the oral cavity, the pharynx, and the upper portion of the œsophagus, where striated fibres are found instead of the former. The external layers (areolar and muscular) present no peculiarities of structure, except such as will be mentioned in connection with that of the mucous membrane of the several portions just mentioned. But the latter presents marked variations in its different portions, and will be particularly described. The *appendages* to be described in this chapter are the liver and the pancreas. The spleen will be described in the chapter upon the blood-vascular glands.

1. *Mucous Membrane of the Oral Cavity.*

The *epithelium* of the oral mucous membrane is of the compound scaly variety, and is continuous with the cuticle and stratum Malpighii of the skin at the margins of the lips. It is not, however, distinctly divisible into the two layers just mentioned; but resembles the stratum Malpighii of the skin, with the undermost laminæ of the cuticle. It undergoes certain modifications upon the papillæ of the tongue, hereafter to be described. Unlike the cuticle, the oral epithelium is easily permeated by fluids; and also from within outwards, by plasma passing from the vessels of the mucous membrane into the mouth.

The *corium* of the oral mucous membrane, though continuous

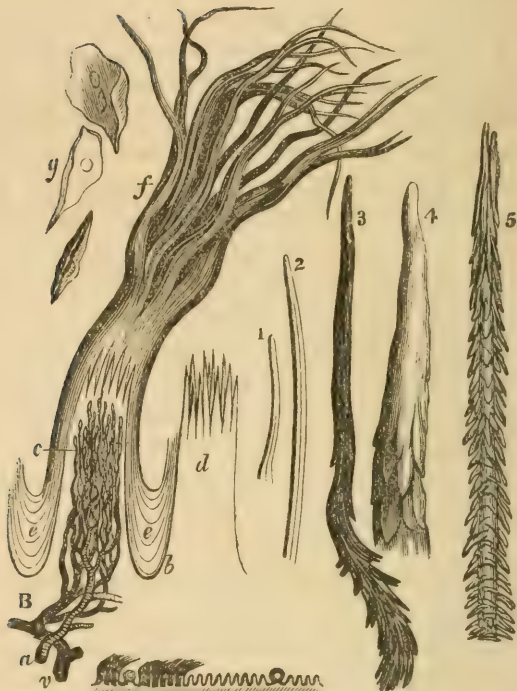
with that of the skin at the border of the lips, is more transparent, soft, and extensible, but possesses considerable firmness. It consists, like the thinnest portions of the latter, of a single layer, formed of collagenous tissue with elastic fibres; presenting a great number of papillæ, like those of the skin, on its outer surface—generally simple, but sometimes double, or even multiple, and standing so close together that their bases are nearly in contact, and rarely more than their own breadth apart. They average $\frac{1}{120}$ to $\frac{1}{66}$ of an inch in length, and $\frac{1}{600}$ to $\frac{1}{300}$ of an inch in breadth. They consist of a slightly granular homogeneous substance.

The papillæ upon the upper surface of the tongue demand a particular description. The corium is also here attached directly and closely to the subjacent muscular tissue, by a dense layer of collagenous tissue. The lingual papillæ are of three kinds: the papillæ *circumvallatæ*, the *fungiformes*, and the *filiformes*, or *conicæ*. All these project freely; but there are also other smaller ones, completely buried in the epithelium, over the whole gustatory region of the tongue.

1. The *papillæ filiformes*, or *conicæ*, are crowded between the fungiformes, and are most abundant on the middle of the tongue. They are conical processes, $\frac{1}{36}$ to $\frac{1}{8}$ of an inch long, by $\frac{1}{120}$ to $\frac{1}{60}$ broad, of the corium of the mucous membrane, divided at their extremities into from five to twenty smaller secondary papillæ, of $\frac{1}{120}$ to $\frac{1}{86}$ of an inch. These are covered by a thick epithelial coat, drawn out into a number of long, thin, fine, and subdivided processes, resembling a fine brush, and sometimes $\frac{1}{24}$ to $\frac{1}{17}$ of an inch long. The whole mass somewhat resembles a hair (Fig. 344), and is liable to be covered with mucedinous fungi. (Fig. 155.) Each filiform papilla has an artery giving a capillary loop to each of the simple papillæ upon it. Nerves also can be found in most, but not all, of them; there being in the base of the papilla one or two small trunks with five to ten dark-bordered nerve-fibres, becoming finer as they approach the point. They probably terminate in loops. (*Kölliker.*) (Fig. 345.)

2. The *fungiform papillæ* abound particularly on the anterior part of the tongue. They consist of a clavate primary papilla, $\frac{1}{40}$ to $\frac{1}{15}$ of an inch long, to $\frac{1}{60}$ to $\frac{1}{24}$ of an inch broad, covered with closely placed, conical, secondary papillæ, $\frac{1}{120}$ to $\frac{1}{100}$ of an inch long, and covered by a simple epithelium, only $\frac{1}{3000}$ to $\frac{1}{2400}$ of an inch thick, over their points. (Fig. 346.) The vessels are arranged as in the

Fig. 344.

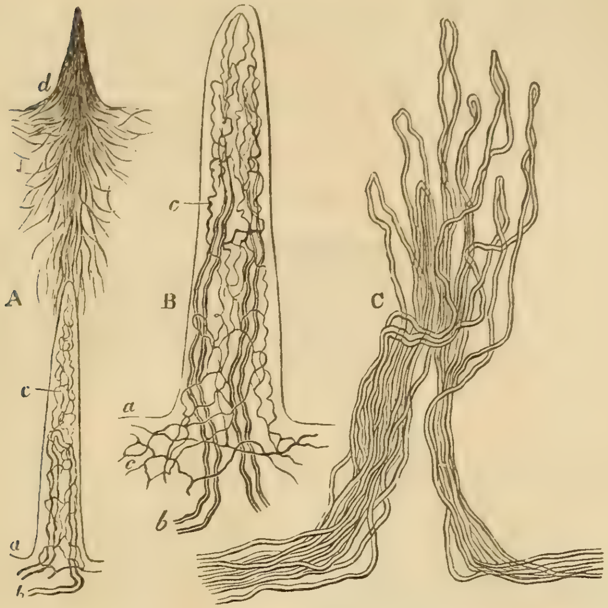


A. Vertical section near the middle of the dorsal surface of the tongue: *a. a*, fungiform papillæ; *b*, filiform papillæ, with their hair-like processes; *c*, similar ones, deprived of their epithelium. (Magnified 2 diameters). B. Filiform papillæ: *a*, artery: *v*, vein; *c*, capillary loops of the secondary papillæ; *b*, line of basement-membrane; *d*, secondary papillæ, deprived of their (*e, e*) epithelium; *f*, hair-like processes like epithelium, capping the simple papillæ (magnified 25 diameters); *g*, separated nucleated particles of epithelium (magnified 300 diameters). 1, 2. Hairs found on the surface of the tongue. 3, 4, 5. Ends of hair-like epithelium process, showing varieties in the imbricated arrangement of the particles, but in all a coalescence of the particles towards the point. 5. Incloses a soft hair. (Magnified 160 diameters.)

papillæ filiformes, except that they are far more numerous. (Fig. 346, B.) One or two larger nervous trunks also ($\frac{1}{3000}$ to $\frac{1}{1500}$ of an inch) enter every fungiform papilla, besides many minute filaments, which, repeatedly anastomosing, spread out like a brush towards the secondary papillæ and their axile corpuscles. They probably terminate both in loops and in free extremities. (*Kölliker.*)

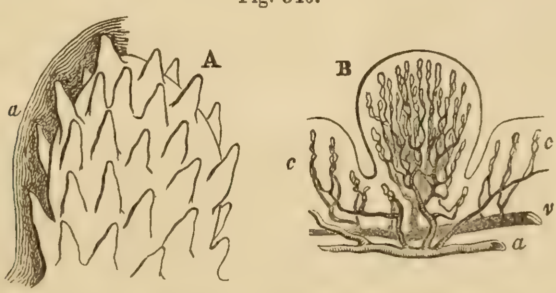
3. The *papillæ circumvallatæ* are situated at the base of the tongue, are six to twelve in number, and consist of a central round papilla, flattened at the end, $\frac{1}{24}$ to $\frac{1}{12}$ of an inch in diameter, and $\frac{1}{48}$ to even $\frac{1}{16}$ of an inch high; with a lower uniform *wall*, $\frac{1}{60}$ to $\frac{1}{36}$ of an inch

Fig. 345.



A. Secondary papilla of the conical class treated with acetic acid: *a*, its basement-membrane; *b*, its nerve-tube, forming a loop; *c*, its curly elastic tissue. The epithelium in this instance is not abundant, but the vertical arrangement of its particles over the apex of the papilla is well seen (*d*), and illustrates the mode of formation of the hair-like processes described in the text. (Magnified 160 diameters.) B. A similar papilla, deprived of its epithelium: *a*, basement-membrane; *b*, tubular (nerve) fibre, probably forming a loop, but its arch not clearly seen; *c*, *c*, elastic fibrous tissue at its base and in its interior. (Magnified 320 diameters.) C. Nerves of a compound papilla near the point of the tongue, in which their loop-like arrangement is distinctly seen. (Magnified 160 diameters.)

Fig. 346.

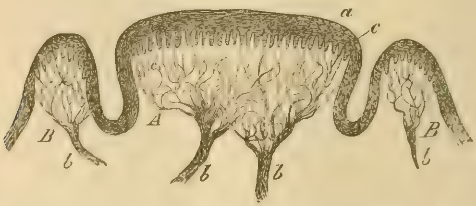


A. Fungiform papilla, showing the secondary papillæ on its surface, and at *a*, its epithelium covering them over. (Magnified 35 diameters.) B. The capillary loops of the simple papillæ of A, injected: *a*, artery; *v*, vein. The groove around the base of some of the fungiform papillæ is here represented, as well as the capillary loops (*c*, *c*) of some neighboring simple papillæ. (Magnified 18 diameters.)

broad, closely surrounding the papilla, especially at its base. They are arranged so as to correspond to the letter V, the point being

constituted by the *foramen cæcum*, which is a depression containing fungiform papillæ. The papilla itself is, in structure, to be regarded as a flattened fungiform papilla, except that it contains no elastic tissue; and the wall is a simple elevation of the mucous membrane, with a smooth epithelium, under which its upper border is produced into many rows of simple conical secondary papillæ. (Fig.

Fig. 347.



Papilla circumvallata of man, in section. *A.* Proper papilla. *B.* Wall. *a.* Epithelium. *c.* Secondary papillæ. *b, b.* Nerves of the papilla and of the wall.—Magnified about 10 diameters. (*Kölliker.*)

347.) Far more nerves are distributed to these than to the fungiform papillæ; the *walls* also being abundantly provided with them.

Uses of the Lingual Papillæ.—The filiform papillæ are neither the seat of the sense of taste, nor delicate tactile organs; but are the analogues of the lingual spines of animals (*Todd and Bowman*), and hence aid in mastication, and in protecting the tongue. The two other kinds of papillæ subserve the sense of taste, and are also the seat of touch, temperature, &c. The sense of *touch* is most acute at the point of the tongue where the fungiform papillæ are most abundant; the sense of *taste* at the root of the tongue, probably because the circumvallate papillæ possess more nerves in the same space. The nerve-fibres are also finer, or more nearly reduced to isolated axis-fibres.

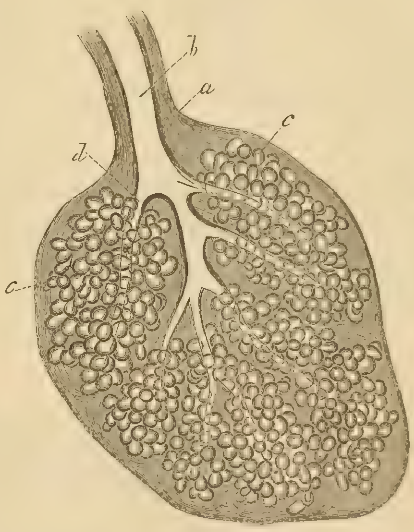
Certain *pathological* appearances of the tongue are easily understood from the data just afforded. The *gastric furred tongue* is produced principally by the growth of the epithelial processes of the filiform papillæ, which projecting backwards apparently form a peculiar white coating. If they become longer, so that the papillæ measure $\frac{1}{8}$ to $\frac{1}{6}$ of an inch, the appearance called the *villous* tongue, not uncommon in various disorders, is produced. At length, indeed, the tongue may seem to be covered with hairs 4 to 6 lines long. In old people, the tongue may present no papillæ at all; they being small and imbedded in the epithelium. Finally, the mucedinous fungi collecting on the papillæ filiformes may produce a thick white coat, as shown by Fig. 155.

The Glands of the Oral Cavity.

The submucous areolar tissue of the mouth presents no peculiarities, except that it is thin and yielding on the fræna of the lips, tongue, and epiglottis, and the floor of the mouth; while it is more solid where mucous glands occur; and is firmly fixed on the root of the tongue, and the soft palate, where there are also large masses of fat in it. The glands are of three classes: the mucous, the follicular, and the salivary glands.

1. The *mucous glands* are racemose, yellowish, or whitish, of a rounded form, and $\frac{1}{8}$ to $\frac{1}{6}$ of an inch in diameter. (Fig. 348.) Their terminal vesicles, or cæca, precisely resemble a simple sebaceous gland. They generally lie in the submucous areolar tissue. On the lips they form a ring about $\frac{1}{24}$ of an inch broad round the oval aperture, commencing $\frac{1}{4}$ of an inch from the red edge of the lips. They are very numerous in the cheeks, but smaller. Those of the hard palate cover only its anterior half; while those of the soft palate are abundant, but diminish towards the free edge of the uvula. Smaller glands also exist on its posterior surface. There are no glands upon the gums. The mucous glands of the root of the tongue are $\frac{1}{24}$ to $\frac{1}{6}$ of an inch in diameter. They form a stratum in some parts very thick, extending almost from one tonsil to the other. They, however, never extend forwards beyond the middle of the tongue. The ducts of some of these glands which lie in the extremity of the genio-glossus muscle, are even half an inch long. Other small glands lie on the margin of the root of the tongue; and two elongated glandular masses $\frac{1}{2}$ to $\frac{5}{6}$ of an inch long, $\frac{1}{6}$ to $\frac{1}{4}$ of an inch thick, and $\frac{1}{4}$ to $\frac{1}{3}$ of an inch broad, lie under the

Fig. 348.



Human racemose mucous gland from the floor of the oral cavity. *a.* Investment of areolar tissue. *b.* Excretory duct. *c.* Glandular vesicles (cæca). *d.* Ducts of the lobes.—Magnified 50 diameters. (*Kölliker.*)

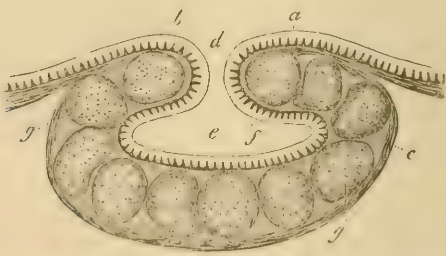
point of the tongue each side of the frænum, where five or six excretory ducts open close to the latter.

All these glands are abundantly supplied with bloodvessels, each of the cæca and vesicles being usually in contact with three or four capillaries. Nerves also exist abundantly upon the excretory ducts, and occasionally fine fibres are found in the glands themselves.

The mucus, secreted by these glands, has already been described (p. 198).

2. The *simple follicular glands* are, when dissected out, $\frac{1}{24}$ to $\frac{1}{6}$ of an inch in diameter, and are found at the root of the tongue lying under the mucous membrane, but above the mucous glands; and so superficially that their position is seen externally. Indeed, the excretory ducts of the mucous glands, before described, open into the bottom of these follicles or sacs. Each of these is a cavity lined by the mucous membrane of the tongue, with its papillæ and epithelium; with a number of large completely closed capsules $\frac{1}{120}$ to $\frac{1}{48}$ of an inch in diameter, and with walls $\frac{1}{6000}$ to $\frac{1}{4000}$ of an inch thick, lying immediately under the membrane in a delicate fibrous and vascular matrix. (Fig. 349.) Their contents are grayish-white, consisting of a clear fluid, cells $\frac{1}{4000}$ to $\frac{1}{2400}$ of an inch in diameter, and free nuclei, $\frac{1}{6000}$ to $\frac{1}{5000}$ of an inch in diameter.

Fig. 349.



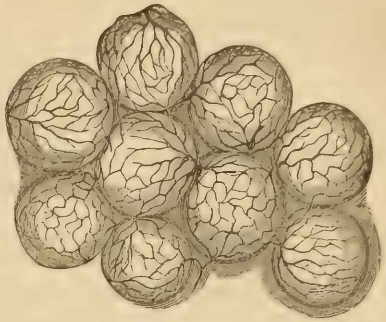
Human follicular gland from the root of the tongue. *a*. Epithelium lining it. *b*. Papillæ. *c*. External surface of the follicular gland with the coat of connective tissue. *e*. Cavity of the gland. *f*. Epithelium. *g*. Follicle in the thick wall of the gland.—Magnified 30 diameters. (*Kölliker*.)

These glands are abundantly supplied with vessels, forming close networks upon the membrane of the capsules (Fig. 350), and then proceeding to supply the papillæ. Lymphatic vessels also proceed from them (*E. H. Weber*), and nerves exist upon them.

Of the *compound follicular glands* the tonsils are an example,

though found in the pharynx. Each of these organs is an aggregation of 10 to 20 compound follicular glands, held together by a common investment, and forming a hemispherical mass. The apertures of the follicles frequently unite so as ultimately to form only a small number on the surface. The structure of the tonsil is, therefore, understood from the previous description of the simple follicular glands. It should also be added, that the tonsils receive the ducts of mucous glands. The vessels distributed to the closed capsules are more numerous than those of the lingual follicles. (Fig. 350.) Nerves exist on the surface of the tonsil and in the papillæ; but have not been found in the membrane of the closed capsules.

Fig. 350.



Vessels of a few follicles from a human tonsil, seen from the cavity of a sac.—Magnified 60 diameters. (*Kölliker.*)

What the precise function of the closed capsules is, is not determined. But at least their contents are very similar to those in the follicular cavity around which they lie, though no capsules are found burst.

3. The *salivary glands* (parotid, submaxillary and sublingual), may be regarded as compound racemose mucous glands, so far as their structure is concerned; their primary lobules corresponding to those of a mucous gland, and their secondary to the entire mucous gland. (Fig. 348). These last are united into larger lobes, and thus the whole salivary gland is made up. (Fig. 316, c.)

The excretory ducts of the salivary glands have a conoidal epithelium consisting of a single layer of cells $\frac{1}{750}$ of an inch long. The remainder of their wall (very thick in Stenon's duct), is a firm and condensed layer of areolar tissue. In Wharton's duct, there is a thin layer of smooth muscular fibres within the areolar tissue; while there is also a double elastic layer between this muscular layer and the epithelium. The vessels are abundantly distributed to the primary lobules, as to those of the mucous glands; the capillaries being $\frac{1}{4000}$ to $\frac{1}{3000}$ of an inch in diameter. Lymphatics are also found in the salivary glands. Nerves proceed into them also,

with the vessels, from the external carotid plexus; besides which, the *ganglion linguale* supplies the two smaller pairs of glands, and the facial nerve, probably with the anterior auricular, the parotid.

The composition and uses of the saliva have already been specified (pp. 209–10).

2. *Mucous Membrane of the Pharynx.*

Only the lower half of the pharynx will be noticed here; the upper half belonging to the respiratory passages. In that part of it through which the food passes, the epithelium is of the compound scaly variety, like that of the oral cavity. The corium of the mucous membrane contains much more elastic tissue than that of the mouth, is paler, and presents none but rudimentary papillæ.

The glands in the lower half of the pharynx are, 1, racemose mucous glands, already described (p. 519), in small numbers; 2, follicular glands—especially on the posterior and lateral walls of the pharynx, as far as to the level of the epiglottis; 3, the tonsils already described (p. 521). The first two kinds of glands are, however, far more abundant on the upper half of the pharynx, as will be shown further on (Chap. XVI.).

Bloodvessels, lymphatics, and nerves, abound in the mucous membrane of the pharynx. The muscles of the pharynx are the three constrictors, the stylo-pharyngeus, and the palato-pharyngeus.

3. *Structure of the Œsophagus.*

While the muscular coat of the pharynx is formed of striated muscular fibres alone (the *constrictores* pharyngis, &c.), that of the œsophagus contains both kinds of fibres. In its upper third, as far as its entrance into the thorax, only the striated muscular fibres are found, arranged in fasciculi $\frac{1}{300}$ to $\frac{1}{50}$ of an inch in diameter, and which sometimes distinctly anastomose. Lower down, the smooth muscular fibres appear, first in the circular (internal) layer; and then increase while the striated fibres diminish—though the latter are found isolated, and extending even to the cardia. (*Ficinus.*)

The mucous membrane is paler than that of the pharynx, and assumes a whitish tint below. It is $\frac{1}{33}$ to $\frac{1}{26}$ of an inch thick; its compound scaly epithelium being $\frac{1}{120}$ to $\frac{1}{100}$ of an inch thick; and whose epithelial plates, constituting one-half its thickness, may be readily stripped off in large white sheets, after a short maceration.

The corium, averaging $\frac{1}{40}$ of an inch thick, presents numerous conical papillæ, and consists, besides areolar tissue, of very many longitudinal bundles of smooth muscular fibres. It also contains fat cells and small racemose mucous glands. (Fig. 348.)

The mucous membrane of the œsophagus is moderately supplied with bloodvessels, lymphatics, and nerves. The last have not yet been traced into the papillæ.

The Infra-diaphragmatic Portions of the Alimentary Canal.

All the infra-diaphragmatic portions of the alimentary canal (except a small part of the rectum) have still another layer external to the muscular coat, viz., the *peritoneum*. This serous membrane forms a closed cavity; its epithelium being of the simple scaly variety. Its corium is much thicker in the external or parietal layer, than in the internal or visceral; though having in both the same structure—like that of the corium of the skin. The whole thickness of the membrane is $\frac{1}{300}$ to $\frac{1}{200}$ of an inch in the latter case, and $\frac{1}{200}$ in the former. A loose sub-serous layer of areolar tissue containing fat-cells exists in most parts; not, however, in the folds of the peritoneum. But few vessels or nerves are distributed to this membrane; and lymphatics have been found only in the sub-serous layer.

Any peculiarity in the *muscular* coat will be specified in connection with the part in which it occurs. In general, it consists of an incomplete layer of longitudinally arranged fasciculi of smooth muscular fibres externally, and another of circular fibres internally. The stomach has also a third layer of oblique fibres inside of the circular layer.

1. *The Structure of the Stomach.*

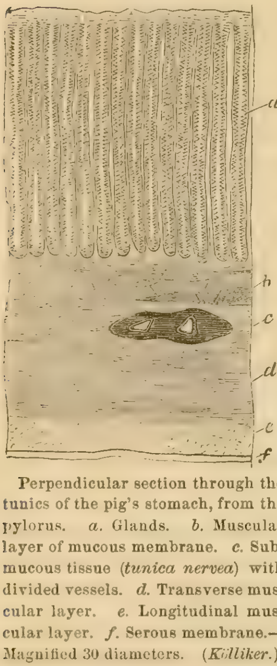
The *mucous membrane* of the stomach is reddish-gray, or bright red during digestion, but at other times grayish. It is thinnest ($\frac{1}{72}$ to $\frac{1}{48}$ of an inch) at the cardia; and thickest in the pyloric region ($\frac{1}{16}$ to $\frac{1}{12}$ of an inch). Little polygonal areas, $\frac{1}{24}$ to $\frac{1}{6}$ of an inch across, bounded by very slight depressions, are not unfrequently found on the pyloric portion of the membrane. Dr. Neil has shown that conical papillæ exist around the pylorus, similar to the villi of the small intestine, but smaller.

The *corium* of the mucous membrane contains a layer of smooth

muscular fibres in its lowest portion, above which all is areolar tissue. The muscular layer and the simple conoidal epithelium are everywhere of the same thickness, while the intermediate portion—the glandular layer—varies.

The most important element of the gastric mucous membrane—the *gastric glands*—are straight tubes passing *through* the membrane down to its muscular layer, and therefore varying in different parts from $\frac{1}{60}$ to $\frac{1}{12}$ of an inch in length. They are so crowded together that very little tissue intervenes between them. (Fig. 351.) They commence on the surface as cylindrical tubes $\frac{1}{4000}$ to $\frac{1}{3000}$ of an inch in diameter, diminish below to $\frac{1}{6000}$ of an inch, or less; and the most common form terminates in a flask-shaped enlargement of $\frac{1}{480}$ to $\frac{1}{133}$ of an inch. Each tube is lined through its upper third by a simple conoidal epithelium; but in the rest of its extent the tube is entirely filled with pale, finely granular, nucleated cells, $\frac{1}{2000}$ to $\frac{1}{1200}$ of an inch in diameter, which do not seem to constitute a distinct epithelium. They are termed the *peptic cells;* and these are the *simple peptic* glands occurring in the middle zone of the stomach. The compound *peptic glands* (Fig. 352, C) occur in the narrow cardiac zone of the stomach. They resemble the preceding, except that they divide into two or three, and then into four to seven equally long cylindrical tubules, also lined by the peptic cells; in which oil-globules are frequently observed. The terminal lobules have a twisted appearance dependent on numerous lateral dilatations. Smooth muscular fibres are also found between these glands. Still, other compound tubular glands also exist in the *pyloric zone*, resembling the last, except that they are larger and lined *throughout* by a conoidal epithelium, and therefore contain no peptic cells. (Fig. 352, B.)

Fig. 351.

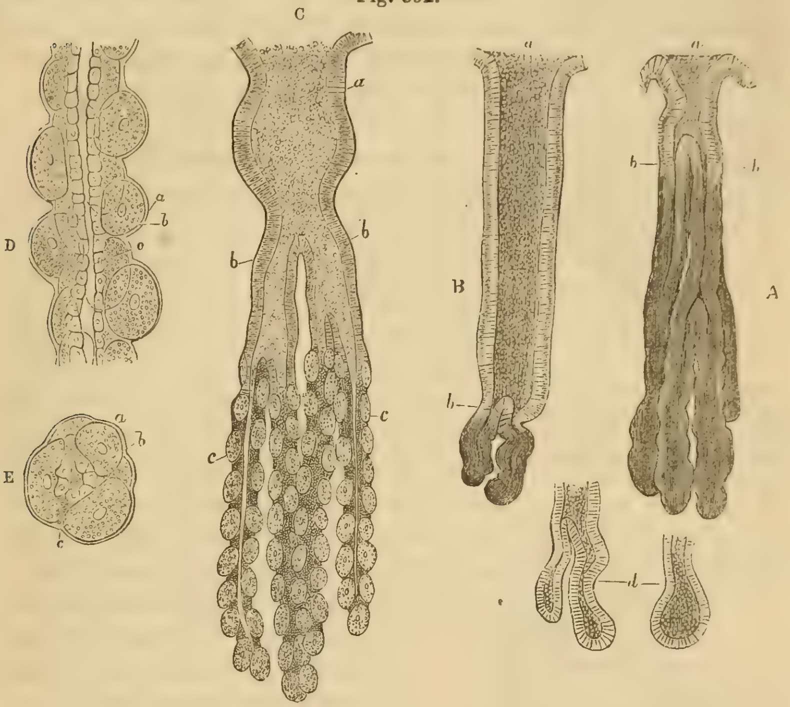


Perpendicular section through the tunics of the pig's stomach, from the pylorus. *a*. Glands. *b*. Muscular layer of mucous membrane. *c*. Submucous tissue (*tunica nervea*) with divided vessels. *d*. Transverse muscular layer. *e*. Longitudinal muscular layer. *f*. Serous membrane.—Magnified 30 diameters. (*Kölliker.*)

It is pretty certain that the true gastric juice is afforded only by the two forms of *peptic* glands just described; while the last men-

tioned secrete mucus alone. The pepsin is, therefore, afforded only by the cardiac and middle zone of the stomach, and not by the pyloric.

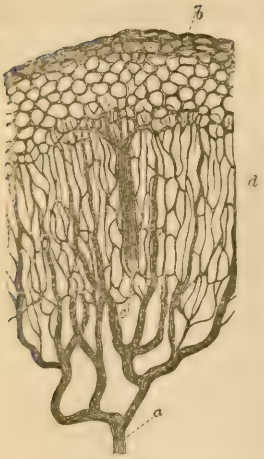
Fig. 352.



A and C. Peptic gastric glands, from the middle of the stomach. B. Mucous gland from pyloric region. *a*, trunk of the glands; *b*, branches; *c*, terminal cæca; *d*, termination of mucous gland, B, lined with conoidal epithelium. D. Portion of cæca of C, magnified 350 diameters. E. The same, transverse section. *a*, basement membrane; *b*, large cells; *c*, small epithelial cells. A and B, from the dog—200 diameters; C, 60 diameters. (*Kölliker.*)

The *bloodvessels* of the gastric mucous membrane are very numerous, and their distribution quite characteristic. Fig. 353 represents those of the large intestine, which are very similar. The arteries, beginning to divide in the submucous areolar tissue, break up into capillaries of $\frac{1}{6000}$ to $\frac{1}{4000}$ of an inch, which ascend between, and form a network around the tubular glands, extending as far as their apertures, and forming polygonal meshes around the latter $\frac{1}{600}$ to $\frac{1}{300}$ of an inch in diameter. From this network the veins rise by many radicles, and penetrating the glandular layer further apart than the arteries, enter a venous network with partly horizontal vessels, in the submucous tissue.

Fig. 353.



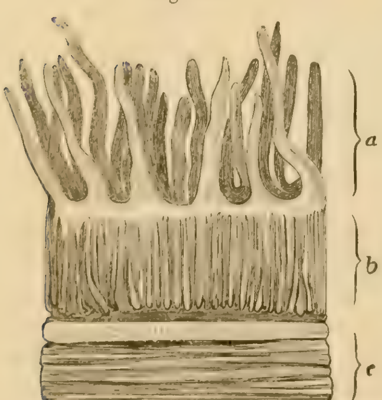
Vessels of the large intestine of a dog, the mucous membrane being cut through perpendicularly. *a.* Artery. *b.* Capillary network of the surface with glandular apertures. *c.* Vein. *d.* Capillary network round the glandular tubules in the thickness of the mucous membrane.—(*Kölliker.*)

The *lymphatic vessels* of the gastric mucous membrane form two networks; a fine, superficial, and a deep, coarse one. The *nerves*, derived from the pneumogastric and the sympathetic, have been seen to enter the muscular layer of the mucous membrane, but have not been traced further.

2. *Structure of the Small Intestine.*

The small intestine is divided into the *duodenum*, the *jejunum*, and the *ileum.*—Throughout, the mucous membrane has a simple conoidal epithelium; and its corium has a layer of smooth muscular fibres both longitudinal and transverse (described by Brücke), like that of the gastric mucous membrane; and, at most, $\frac{1}{700}$ of an inch thick. Where certain glands exist, there is but little submucous tissue, the corium being closely connected with the muscular tunic of the intestine. It is more complicated in structure, though thinner than the membrane of the stomach; presenting, as it does, the villi and several varieties of glands.

Fig. 354.



Section of the mucous membrane of the small intestine of the dog, showing Lieberkühn's follicles and the villi. *a.* Villi. *b.* Lieberkühn's follicles. *c.* Other coats of the intestine.

I. The *villi* (Fig. 354) extend throughout the small intestine from the pylorus to the sharp edge of the ileo-cæcal valve, being most numerous (50 to 90 upon a square line) in the duodenum and jejunum; while there are but 40 to 70 on the same surface in the ileum. They are whitish elevations of the corium of the mucous membrane, easily seen by the unaided eye, and are set so close together upon and between the

valvulæ conniventes as to give to the membrane its velvety appearance. In the *duodenum* they are broader and less elevated, resembling folds and laminæ $\frac{1}{120}$ to $\frac{1}{48}$ of an inch high, and $\frac{1}{72}$ to even $\frac{1}{16}$ of an inch broad. In the *jejunum* they are mostly conical and flattened, and often cylindrical, clavate, or filiform; being $\frac{1}{60}$ to $\frac{1}{24}$ of an inch long, $\frac{1}{72}$ to $\frac{1}{120}$ of an inch, or less, in breadth, and $\frac{1}{240}$ of an inch (in the flattened forms) thick. The *epithelium* of the villi is the simple conoidal variety. The proper villus itself is simply a solid process of the corium whose matrix is undeveloped collagenous tissue, in which a variable number of roundish free nuclei are scattered; containing bloodvessels, lymphatics, and smooth muscular fibres. The *bloodvessels* are very numerous. Two or three small arteries ($\frac{1}{1200}$ to $\frac{1}{750}$ of an inch) give off a close network of capillaries, $\frac{1}{4000}$ to $\frac{1}{2500}$ of an inch in diameter, which lies immediately beneath the basement membrane on the outer surface of the proper villus itself. From the gradual confluence of these capillaries a vein arises which carries the blood into the larger trunks of the submucous tissue. (Fig. 355.) The *lympha-*

Fig. 355.

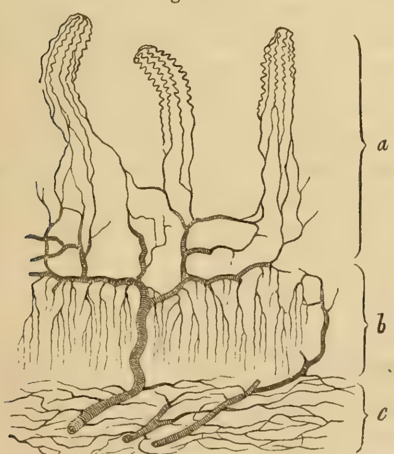


Fig. 355. Vertical section of the coats of the small intestine of a dog, showing only the commencing portions of the portal veins, and the capillaries. The injection has been thrown into the portal vein, but has not penetrated to the arteries. *a*. Vessels of the villi. *b*. Of Lieberkühn's tubes. *c*. Of the muscular coat.

Fig. 356.

Fig. 356. Two villi without epithelium, and with the lacteals in their interior (from the calf); treated with a dilute solution of caustic soda.—(*Kölliker.*)

tics of the villi are usually called *lacteals.* These traverse the axis of the villus, commencing in a cæcal and frequently enlarged end. (Fig. 356.) They have a much greater diameter than the capillaries, and, according to Professor Brücke, are mere excavations in the villi without walls, while the true chyliferous vessels commence in the deeper parts of the membrane. In some broad villi, two lacteal *cavities*, a long and a short, appear.

The *smooth muscular fibres* of the villi are arranged longitudinally, forming a thin layer, not always distinct in man, placed centrally around the lacteals. They produce contractions, and thus influence the propulsion of the chyle and the venous blood in the villi.—Nothing is known of any *nerves* in them.

Function of the Villi.—The villi are the principal agents of absorption of the nutritive elements resulting from the digestion of the food. But Brücke shows that absorption also occurs on the surfaces between them, and particularly from between the glands of Lieberkühn. It is generally asserted that the lacteals alone absorb fat, while the minute bloodvessels absorb the other elements. Brüch, however, found that the bloodvessels absorb fat as well as the lacteals; the former sometimes being half filled with fat, instead of blood alone. Both these observers also show that the epithelium of the villi is not cast off during normal digestion, as stated by Mr. Goodsir. Brücke asserts that the epithelial cells are mere tubes, closed externally by a layer of mucilaginous substance easily permeable by fluids, and that the fat therefore finds an easy admission into them, and to the surface and into the substance of the proper villus itself, in the form of oil-drops. This observation needs confirmation.

In *cholera*, the epithelium of the villi, and sometimes of the whole intestine, is thrown off.

II. The *glands* of the small intestine are of two kinds, the tubular and the racemose. Certain closed follicles are, however, also to be described in this connection.

1. The *tubular*, or Lieberkühn's, glands are distributed over the whole small intestine, as straight, narrow cæca (Fig. 357), extending completely through the mucous membrane, and occupying almost all the space left between the villi; and, in a vertical section (Fig. 359 and 362), resembling palisades. They are, however, not found over the centre of the closed follicles, as will be seen. Their length equals the thickness of the mucous membrane ($\frac{1}{60}$ to $\frac{1}{84}$ of an inch);

their breadth is $\frac{1}{428}$ to $\frac{1}{333}$ of an inch; and their aperture is $\frac{1}{600}$ to $\frac{1}{400}$ of an inch. They contain a simple conoidal epithelium, whose cells

Fig. 357.

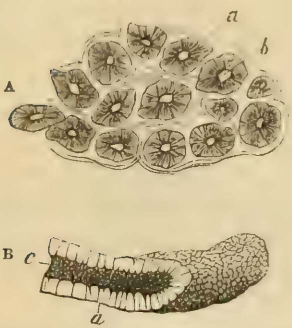


Fig. 358.

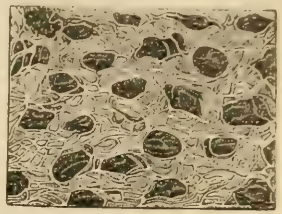


Fig. 357. A. Transverse section of Lieberkühn's tubes or follicles, showing the basement-membrane and the sub-conoidal epithelium of their walls, with the areolar tissue connecting the tubes: *a*, basement-membrane and epithelium constituting the wall of the tube; *b*, cavity or *lumen* of the tube. (Magnified 200 diameters.) B. A single Lieberkühn's tube, highly magnified; an accidental section in the oblique direction displays very distinctly the form and mode of packing of the epithelial cells, the cavity of the tube, and the mosaic pavement of its exterior: *a*, basement-membrane: *c*, internal surface of the wall of the tube. (Magnified 200 diameters.)

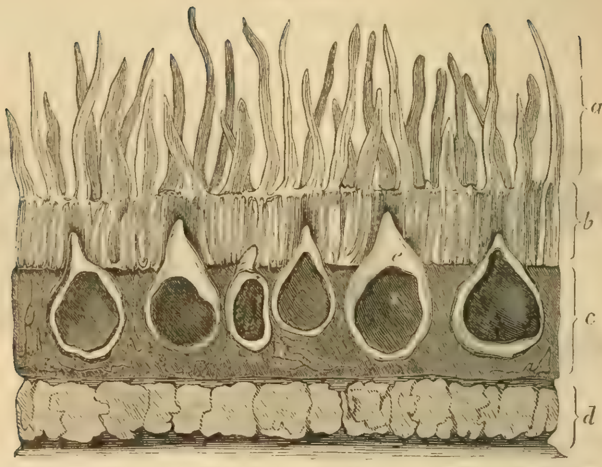
Fig. 358. Distribution of capillaries around follicles of mucous membrane.

during digestion never contain fat, like those of the villi; the *lumen* of the tube being filled by a clear fluid secretion—the *intestinal fluid*—already described on page 201. The vessels of these glands follow the type of those of the stomach. (Figs. 358, 355, and 353.)

2. The *racemose* glands—Brunner's glands—most abundant in the duodenum, resemble those of the oral cavity and the salivary glands, in structure, and their vessels have the same arrangement as those of the latter. (Fig. 348.) Thus the vessels whence the secretion of these and the preceding glands is obtained are next to the arteries, while those concerned in absorption (those of the villi) are further from them, and nearer to the veins. (Fig. 355.)

3. The *closed follicles* are found scattered simply or in groups over the walls of the small intestine. In groups, they constitute the Peyer's patches, or *glandulæ agminatæ*. Each closed follicle is $\frac{1}{72}$ to $\frac{1}{24}$ or even $\frac{1}{12}$ of an inch in diameter, rounded or conical towards the intestinal cavity, and lying partly in the corium of the mucous membrane, and partly under it; extending from a point $\frac{1}{600}$ to $\frac{1}{400}$ of an inch beneath its surface to the muscular tunic, which is here more closely united with the corium. (Fig. 359.) On the surface of the mucous membrane are roundish depressions, $\frac{1}{36}$ to $\frac{1}{12}$ of an inch apart, corresponding to the separate follicles, and presenting

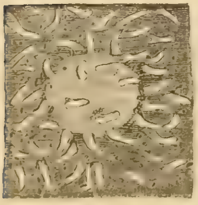
Fig. 359.



Vertical section through a patch of Peyer's glands in the dog. *a.* Villi. *b.* Glands of Lieberkühn, with the apices of Peyer's glands. *c.* Submucous tissue, with the glands of Peyer imbedded in it. *d.* Muscular and peritoneal coats. *e.* Apex of one of Peyer's glands projecting among the tubes of Lieberkühn. *s.* Its contents. The glands are seen laid open by the section. (Magnified about 20 diameters.)

no villi. When, however, the follicles are isolated (glandulæ solitariæ), they usually present a convex surface, and support villi. (Fig. 360.) Each follicle has a completely closed, thick, and strong coat of indistinctly fibrillated collagenous tissue, with interposed nuclei; within which are the soft grayish contents, consisting of a little fluid, and innumerable nuclei and round cells, $\frac{1}{3000}$ to $\frac{1}{1500}$ of an inch in diameter. Very fine bloodvessels ramify, like those of the closed follicles of the tonsils, on the exterior of these follicles (Fig. 350), and penetrate to their interior. (*Frei and Ernst.*) *Lymphatics* also form networks around them; but do not enter them, as Brücke asserted. (*Kölliker.*)

Fig. 360.

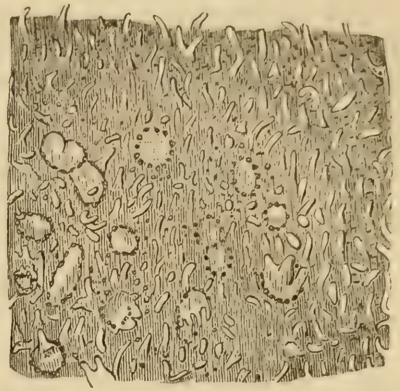


A solitary gland from the small intestine of the human subject. — Magnified. (After *Boehm.*)

The *patches of Peyer* are from 20 to 30 in number, when confined, as usual, to the ileum and lower part of the jejunum; from 50 to 60 when extending nearly to, or even into, the duodenum. They are rounded or elliptical in form, always situated on the portion of intestine opposite the mesentery, and are $\frac{1}{8}$ of an inch to even 1 inch long, and $\frac{1}{4}$ to even $\frac{3}{4}$ of an inch broad. They are mere aggregations of the closed follicles just described, each

follicle being surrounded by the apertures of Lieberkühn's glands, 6 to 10 in number, as shown by Fig. 361.

Fig. 361.



Portion of one of the patches of Peyer's glands, from the end of the ilium; moderately magnified. The villi and Lieberkühn's glands are also displayed.

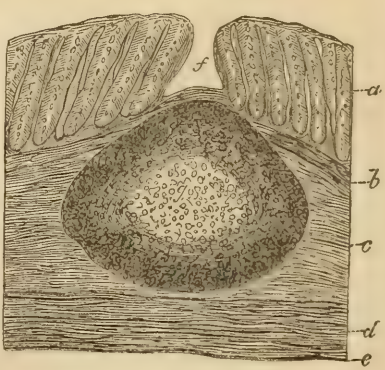
We have as yet no certain knowledge of the functions of the closed follicles of the small intestine. They become ulcerated in typhoid fever, and are subject to various other pathological conditions.

3. *Mucous Membrane of the Large Intestine.*

This agrees mainly in structure with the mucous membrane of the small intestine. Its peculiarities, therefore, will alone be specified. It presents no villi, but, aside from occasional wart-like elevations, it is level and smooth. The muscular layer is difficult to detect, except in the mucous membrane of the rectum.

The *glands* of the large intestine are: 1. Lieberkühn's glands, precisely resembling those of the small intestine, except that they are longer and broader, to correspond with the greater thickness of the membrane ($\frac{1}{48}$ to $\frac{1}{60}$ of an inch, by $\frac{1}{144}$ to $\frac{1}{240}$). They are distributed over the whole surface from the ileo-cæcal valve to the anus. 2. The *solitary closed follicles* are very frequent in the colon and rectum, and usually more abundant in the latter than in the small intestine. They are larger than in the latter locality ($\frac{1}{16}$ to even $\frac{1}{8}$ of an inch in diameter), and upon each of the little prominences to which the follicles give rise there is a

Fig. 362.



Solitary follicle from the colon of a child. *a.* Lieberkühn's glands. *b.* Muscular layer of the mucous membrane. *c.* Submucous tissue. *d.* Transverse muscular fibres. *e.* Serous membrane. *f.* Depression of mucous membrane above the follicles *g.*—Magnified 45 diameters. (*Kölliker.*)

small, pit-like, elongated or rounded aperture, $\frac{1}{108}$ to $\frac{1}{144}$ of an inch in diameter, in the mucous membrane. (Fig. 362.) The function of these closed follicles is also unknown.

The bloodvessels of the preceding glands have the same relations as in the small intestine. (Fig. 353.) Nothing is known of either the lymphatics or the nerves of the mucous membrane of the large intestine.

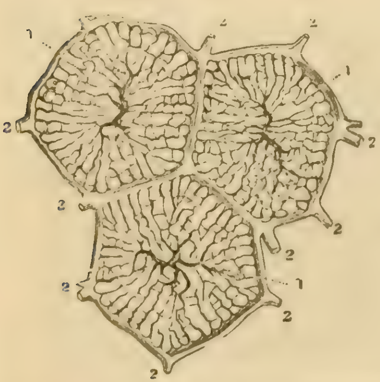
The Appendages to the Alimentary Canal.

1. *The Liver.*

Referring to the works on descriptive anatomy for all other particulars in regard to the liver, such only will be specified here as are necessary to give an idea of its minute structure.

The vena portæ, the hepatic artery, and the hepatic duct enter the transverse fissure of the liver, and, subdividing, at last terminate—the first two in a capillary plexus from which the hepatic vein commences, and the last in immediate contact with the plexus. In the pig, and some other animals, the minute structures just mentioned are so inclosed as to constitute distinct lobules, and it is the lobules in this animal which Kiernan first accurately described and figured. In man, however, nothing of the kind occurs, as E. H. Weber first demonstrated; the various structural elements being intimately connected throughout the whole organ. Still, the distribution of the capillaries and ducts is such as to give rise to little *islets* in the liver, somewhat analogous to the lobules above mentioned. These are masses of the hepatic substance, $\frac{1}{36}$ to $\frac{1}{12}$ of an inch in diameter, containing some of the minutest branches of the vena portæ and the hepatic artery externally, and giving off in their centre a small twig of the hepatic vein. Between these vessels the portal hepatic plexus of capillaries is found. (Fig. 363.) The hepatic ducts arise in the meshes between the vessels of

Fig. 363.



Horizontal section of three superficial lobules of the liver, showing the two principal systems of bloodvessels. 1, 1. Interlobular veins proceeding from the hepatic veins. 2, 2. Interlobular (portal-hepatic) plexus, formed by branches of the portal vein. (Pig.)

the plexus, and accompany the finest ramifications of the portal vein, so that the bile flows in a direction opposite to that of the blood. Finally, the spaces in the islets left between the elements just described are occupied by the so-called *hepatic cells*. Thus, in general, is an *islet* in the human liver composed; the capillary plexus, however, being common to all the contiguous islets, and continuous between them. The capsule of Glisson, composed of areolar tissue, invests the vena portæ, hepatic artery, and hepatic duct, as far as to the branches going to the islets; but it extends between, and isolates the latter into distinct lobules, only in the pig, so far as has yet been ascertained.

The passages in the liver containing Glisson's capsule with the vessels just mentioned, are called the *portal canals*. (Fig. 364.)

Fig. 364.

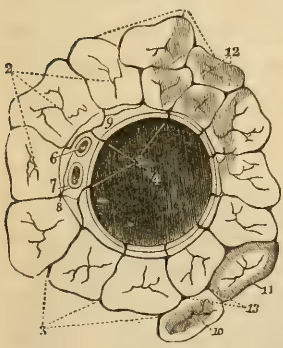


Fig. 365.

Fig. 364. A transverse section of a small portal canal and its vessels; after Kiernan. 4. Portal vein. 9. Interlobular branches. 5. Branches of the vein, also giving off interlobular branches (vaginal branches, *Kiernan*.) 7. Hepatic duct. 6. Hepatic artery. 2. Hepatic vein. The lobules are seen in outline.

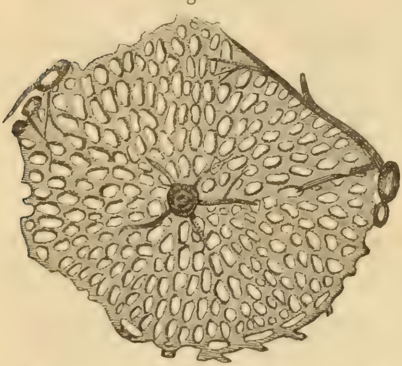
Fig. 365. Hepatic cells of man. *a*. Normal cells. *b*. With pigment. *c*. With fat —Magnified 400 diameters. (*Kölliker*.)

More particularly, the *hepatic cells* (Fig. 365) are described by Kölliker as averaging $\frac{1}{1500}$ to $\frac{1}{1000}$ of an inch in diameter, the extremes being $\frac{1}{2000}$ and $\frac{1}{750}$ of an inch. Their membrane is smooth and delicate, and their normal contents are—1*st*, a yellowish, granular, semi-fluid substance; 2*dly*, a round, vesicular, nucleolated nucleus, $\frac{1}{4000}$ to $\frac{1}{3000}$ of an inch in diameter (and sometimes two of these). Besides these (3*dly*) fat-drops, and (4*thly*) pigment-granules are frequently to be met with. The last hardly exceed $\frac{1}{12000}$ of an inch in diameter, are of a yellow or brownish-yellow color, and appear to be chemically identical with the coloring matter of the bile (p. 101).

These cells are so arranged in the islets as to *appear* to form a *network* by the mere apposition of their flat surfaces, without any intermediate substance or investing coat. The meshes of the network are mere perforations and passages for the capillary plexus and the commencement of the hepatic vein, and are of course conformed to their diameters. The cells are generally arranged in from one to three rows (rarely four or five), to form the network itself (Fig. 118), so that the meshes are thus $\frac{1}{1200}$ to $\frac{1}{800}$ of an inch apart. Their true relation to the minute hepatic ducts will be specified on page 536.

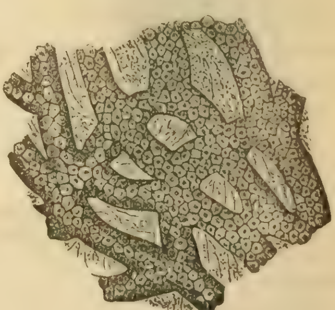
The hepatic *ducts* had been traced *to* the margin of the hepatic islets by Kölliker, but not *into* them; and he suggests that the finest ducts are open at their extremity, and abut on the hepatic cells, as shown by Fig. 118. Far more probable, however, was the view of Prof. Leidy on this subject, viz., that the hepatic ducts commence in the substance of the islets as a network of distinct tubules, lined by a basement-membrane and an epithelium.[1] (Figs. 366 and 367.)

Fig. 366.



Transverse section of a lobule of the human liver, showing the reticular arrangement of the bile-ducts; with some of the branches of the hepatic vein in the centre, and those of the portal system at the periphery.

Fig. 367.

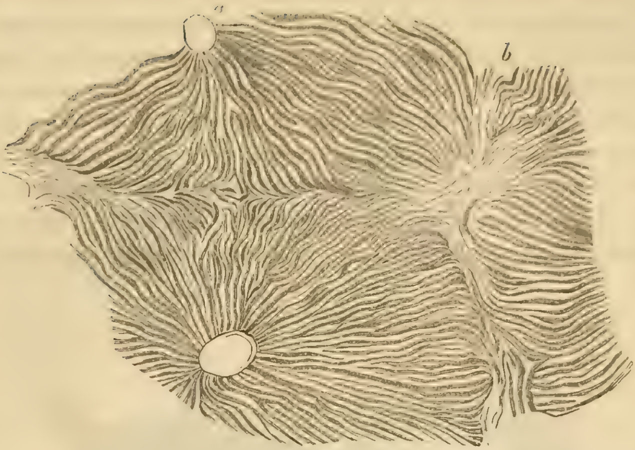


A small portion of the preceding section, more highly magnified, showing the secreting cells within the tubes. (*Leidy.*)

But Dr. Beale's recent investigations on this point seem quite conclusive. He finds the hepatic cells to be arranged in lines radiating from the centre of the lobule, as shown in Fig. 368; though precisely this appearance is presented only when the section is made at right angles to the small twig of the hepatic vein in the centre of

[1] Researches into the Comparative Structure of the Liver, American Journal of the Medical Sciences, Jan. 1848.

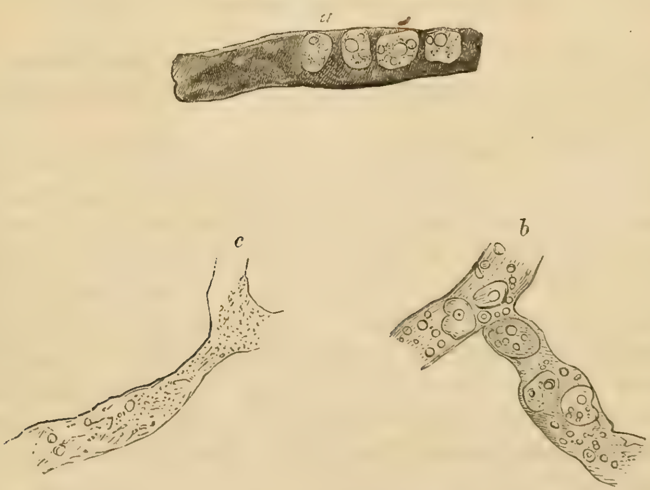
Fig. 368.



Transverse section of hepatic islets (horse), showing the secreting cells forming lines radiating from the hepatic vein (*a*) in the centre, towards the circumference (*b*). Injected with vermilion. (*Dr. Beale.*)

the islet. There is usually but one row (sometimes two) of cells between the capillary vessels. He further ascertained that these rows of cells are contained *within tubes* formed of simple membrane; which is sometimes incorporated with the walls of the capillaries, and sometimes distinct from them. (Fig. 369.) These cell-containing *tubes*, therefore, form the network in the substance of the islet.

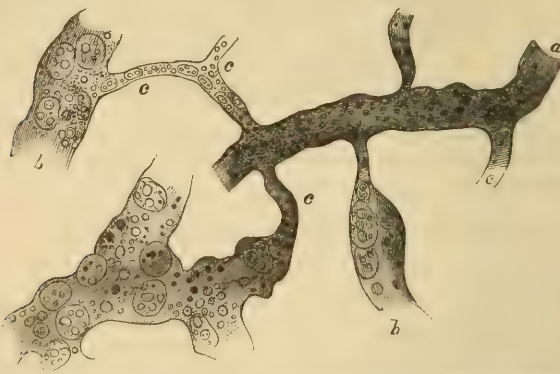
Fig. 369.



Tubes of simple membrane containing the liver-cells (pig). *a.* An injected specimen, the shades showing the injection. *b.* Cells and free oil-globules within the tube. *c.* Tube in which the cells have been disintegrated.—Magnified 200 diameters. (*Dr. Beale.*)

The precise connection of the ducts between the lobules, and the tubes just mentioned, is as follows: Numerous finer branches leave the small trunk of the duct, in the spaces between the islets, and pass towards the secreting cells, without branching or anastomosing with each other; and, pursuing a tortuous course around the branches of the portal vein, pass at once to the cell-containing network of tubes just described, and with which they are continuous. Near to the point where the duct joins the network of cell-containing tubes, it becomes very much narrowed; being frequently $\frac{1}{5000}$

Fig. 370.



Communications of interlobular ducts. *a.* With the cell-containing tubular network. *b.* Part of tubes containing cells filled with oil and free oil-globules. *c.* Narrowest portions of the ducts (pig.) The shaded parts are filled with injection.—Magnified 215 diameters. (*Dr. Beale.*)

of an inch, or even less, in diameter in the uninjected state. Fig. 370 represents the narrowest ducts in the pig, and Fig. 371 those in the human liver.

The *epithelium* lining the minute ducts between the islets ($\frac{1}{1200}$ of an inch in diameter) is of the simple scaly variety; its cells being far smaller than the secreting cells in the network before described, or only about $\frac{1}{5000}$ of an inch in diameter. Fig. 372 shows their size compared with that of the former. It terminates abruptly where the secreting cells begin. In the ducts $\frac{1}{300}$ to $\frac{1}{240}$ of an inch in diameter, the epithelium is more conoidal; and it becomes completely so in those above $\frac{1}{120}$ of an inch. The latter also have a dense layer of areolar tissue (corium) externally to the epithelium and basement-membrane. The *ductus communis choledochus*, and the *cystic duct*, have both a mucous layer and a submucous areolar layer; the former containing a few smooth muscular fibres, but no

special muscular coat. The *gall-bladder* has a layer of smooth muscular fibres beneath its peritoneal covering. That of the ox may be made to diminish its capacity one-fourth by a powerful galvanic

Fig. 371.

Fig. 372.

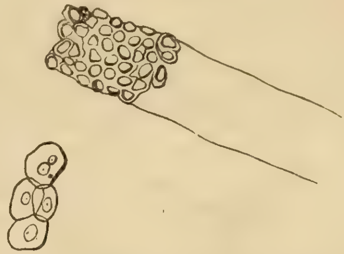


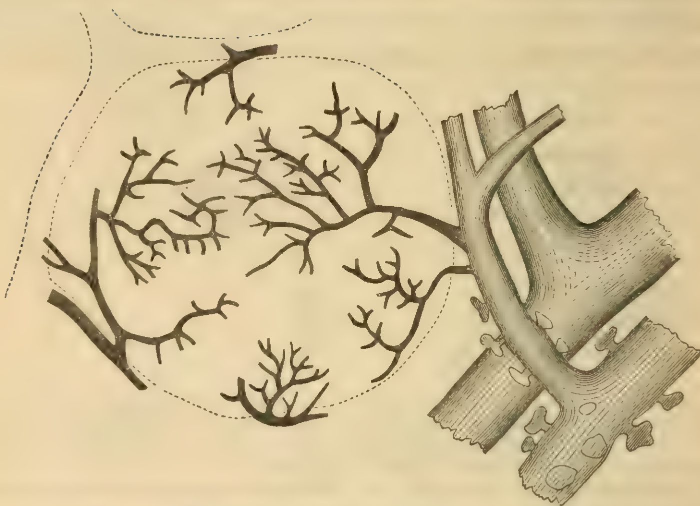
Fig. 371. Narrowest portions of bile-duct, lined by its epithelium, continuous into the tubes containing the hepatic cells. A venous capillary and a small branch of the artery are seen in section, close to the narrow duct. The liver-cells have been destroyed by the reagents used in preparing the specimen. (Human.)—Magnified 215 diameters. (*Dr. Beale.*)

Fig. 372. Terminal portion of interlobular duct, containing its epithelium, with four hepatic cells to show the comparative size.

battery. (*Dr. Mayer.*) Its mucous membrane presents many reticulated, more or less prominent, folds, containing a capillary network exactly like that of the foliaceous intestinal villi. It has also a conoidal epithelium.—Finally, the mucous membrane of the hepatic ducts above $\frac{1}{125}$ of an inch in diameter contains a multitude of small, racemose, yellowish mucous glands (*Kölliker*) or *sacculi* (*Dr. Beale*); while there are but few in the cystic duct, and usually none at all in the gall-bladder. Dr. Beale finds these generally to be simple oval pouches, arranged in two rows on opposite sides of the duct, and connected with its cavity by a very narrow neck, often not $\frac{1}{5000}$ of an inch in diameter. In the larger ducts they are, however, branched, and often run for some distance in the coats of the duct. Occasionally the branches of one gland anastomose with those of another. Fig. 373 shows the more simple, and Fig. 374 the complicated forms of these pouches in the pig; where they are arranged completely around the duct.

Many of the smaller ducts, about $\frac{1}{30}$ of an inch in diameter, have numerous cæcal pouches, arranged pretty closely together, and giving off branches of simple membrane only. These are very numerous in the transverse fissure of the liver, where they form an intricate network connected with the larger branches of the duct. They were first noticed, and named *vasa aberrantia*, by Weber; and who also described the anastomosis between the right and left

Fig. 373.



A small lobule, showing the duct branching upon the capsule (pig). The sacculi of the ducts are seen as injected. A branch of the portal vein accompanies the duct.

hepatic ducts in the transverse fissure, by the intervention of their irregular branches.

Fig. 374.

Large sacculi or glands in the coats of the ducts (pig). The largest and most complicated at *c*, where a smaller branch is coming off from the main trunk. *a*. Portion of large duct. *b*. A small branch without glands.—Magnified 10 diameters. (*Dr. Beale.*)

Dr. Beale considers these cavities or irregular branches "as little reservoirs in which the bile in the thick-coated ducts is brought into closer proximity with the numerous vessels surrounding them;

by which it loses some of its water, and probably undergoes other changes."

Thus the secreting cells at the surface of the islets probably take the most active part in the secretion of bile, being first reached by the portal blood, and while it also circulates more slowly. These cells also first show an increase of oil-drops in cases of fatty degeneration. The bile is formed by each individual cell, and transferred, by the tube inclosing the row of cells, to the ducts between the islets. The very close contact in which the cells sometimes lie, is accounted for by the great changes in bulk they are known so readily to undergo. Hence the liver is a true gland, like the other racemose glands; and not essentially distinct from them in structure, as has generally been asserted.

The *capillary network* of the islets completely fills the interspaces of the tubular network, before described (Fig. 118). The capillaries average about $\frac{1}{3000}$ to $\frac{1}{2200}$ of an inch in diameter; being somewhat less than the rows of the cells in the tube-network. The meshes between the vessels of course correspond in diameter with that of the columns of the cells, being $\frac{1}{2000}$ to $\frac{1}{600}$ of an inch. A transverse section of the islets (in the pig), is shown by Fig. 363, where the formative radicles of the intra-insular hepatic vein is seen in the centre, and the capillary communications on the other hand with the vena portæ, in the perimetral portion. The latter, however, even in the pig, does not form a complete ring round each lobule. The blood probably moves more slowly in the outer part of the capillary network; where it is more richly charged with the constituents of the bile. The external cells also usually contain the most fat; the central the most colored granules.

The *hepatic artery* also terminates in the outer part of the capillary plexus of each islet, with the vena portæ, it having previously supplied the walls of the vessels, and the intra-insular spaces (the capsules of the lobules, in the pig). In regard to the *lymphatics* and *nerves* of the liver, the works on descriptive anatomy may be consulted. That some twigs from the diaphragmatic nerve are sent to this organ, was first announced by Luschka.

Dr. Beale finds the *chemical composition* of the liver to be as follows:—

Water	68.58
Solid residue	31.42

Fatty matter	3.82	31.42
Albumen	4.67	
Alkaline salts	1.17	
Earthy salts	.33	
Extractive matter	5.40	
Vessels, &c., insoluble in water	16.03	

Function of the Liver.—1. The liver secretes the bile, whose properties have already been specified (p. 212). And all analogy warrants the idea that it is secreted by the true hepatic cells lying in the meshes of the portal-hepatic plexus, and which are contained in the tubes which have been described. It is also very certain that the bile is *formed* in the cells and not merely eliminated from the blood (p. 211). 2. But the liver also forms *sugar*, as has already been shown (p. 71); and probably its parenchymal cells are the agents employed in its formation. 3. Again, the liver produces a change in the alimentary substances (albumen, &c.), while traversing it from the vena portæ, after being first absorbed into the vessels of the intestinal villi. It even *forms* fat as well as sugar, when neither are contained in the food; and thus becomes a sort of *equilibrator* of the function of *hæmatosis*, or the development of blood.

Of its *pathological* conditions, fatty degeneration has already been described at some length (p. 311, 5).

In *cirrhosis* of the liver, there is an enormous increase of the areolar tissue inclosing the vascular trunks (except the hepatic vein) and the hepatic ducts; and the individual islets may become prominent, or even form isolated lobules. Since also this increase of the connective tissue is consequent upon the organization of plasma exuded by an inflammation of Glisson's capsule, and the new formation subsequently contracts—the liver is thus rendered more solid and smaller; the true hepatic substance also becoming atrophied, or in part disappearing.

In *jaundice*, the pigment-granules are abnormally increased in the hepatic cells; they sometimes completely filling the latter.

For its other *pathological* conditions, reference must be had to the treatises on pathological anatomy.

2. *The Pancreas.*

The pancreas is a compound racemose gland, so similar in its minute structure to the salivary glands, that only its peculiarities will be here described. The terminal cæca of the pancreatic duct are $\frac{1}{600}$ to $\frac{1}{300}$ of an inch in diameter, and usually rounded, and are lined by a simple scaly epithelium whose cells are frequently

remarkable for their number of fat-granules. The pancreatic duct is lined by a mucous membrane, an offset from that of the duodenum, with a simple conoidal epithelium; and presenting many small racemose glands—probably analogous to the mucous glands of the bile-ducts. (*Kölliker.*)

The bloodvessels are distributed precisely as those of the parotid gland; while the lymphatics are more numerous. The nerves only accompany the vessels, and rise from the great sympathetic.

The secretion of the pancreas is of the greatest importance to the function of digestion, as has been explained on page 213.

CHAPTER XIV.

THE URINARY APPARATUS.

The urinary organs are the kidneys, the ureters, the bladder, and the urethra. The mucous membrane lining the last three, forms the *urinary passages*; while that of the uriniferous tubes of the kidneys is the seat of the secretion itself. The urinary passages will be first described, and then the substance of the kidney.

1. The *urethra* of the *male* will be described with the sexual organs (p. 550). That of the female has a reddish mucous membrane, with a compound scaly epithelium, and a quite vascular corium. The latter also contains, especially near the bladder, a certain number of racemose mucous glands (Littre's glands, Fig. 380), like those of the bladder, except that they are larger (sometimes even $\frac{1}{16}$ of an inch in diameter), and more closely placed. It has a tunic of longitudinal and transverse smooth muscular fibres, intermixed with areolar tissue; and outside of this, the *musculus urethralis* (*Kölliker*), consisting principally of transverse fibres. In the submucous areolar tissue is a plexus of veins, which has been incorrectly described as a *corpus spongiosum.*

2. The *bladder* has, externally to its lining mucous membrane, two layers of smooth muscular fibres: 1, an internal, consisting of oblique and transverse fasciculi, incompletely covering the mucous membrane from their reticular arrangement, but constituting a strong circular layer at the neck of the bladder (the sphincter ve-

sicæ); and 2, an external layer of parallel longitudinal fasciculi (the *detrusor urinæ*).

The *mucous membrane* is pale, smooth, and rather thick, except where the vesical triangle is situated; and most vascular at the fundus and the neck of the bladder. Its nerve-fibres are principally confined to the same parts, are dark-bordered, and both fine and of medium size. Its epithelium generally approaches the compound scaly kind, and, like that of the pelvis of the kidney, is remarkable for the diversity in form and size, of its cells—the deeper being usually elongated, and the superficial rounded, polygonal, or flattened. A conoidal epithelium, however, exists near the urethra and the orifices of the ureters. The corium is level (presenting no papillæ), and shows isolated or aggregated simple racemose mucous glands in the neck of the bladder and towards the fundus. These are $\frac{1}{300}$ to $\frac{1}{50}$ of an inch in diameter, and their orifices are $\frac{1}{600}$ to $\frac{1}{240}$ of an inch. They have a conoidal epithelium. In pathological conditions these are sometimes enlarged and filled with whitish mucous plugs. (*Virchow.*) There is an abundant submucous layer of areolar tissue, except over the vesical triangle; and which is thrown into numerous folds when the bladder contracts.

3. The *ureters*, including also the pelvis and the calices of the kidney, are composed of an external fibrous coat, a middle muscular coat, and a mucous membrane. 1. The fibrous coat is composed of areolar tissue, and where the calices surround the *papillæ*, is continuous with the fibrous coat of the kidney. 2. The muscular tunic consists of an external longitudinal, and an internal transverse layer of smooth fibres; longitudinal fibres being also added to the inner layer towards the bladder. The two muscular layers are as thick in the pelvis of the kidney as in the ureters lower down; becoming thinner in the calices, and ceasing where the latter are inserted into the papillæ. 3. The *mucous membrane* is thin throughout, tolerably vascular, without glands or papillæ, and is continued upon the renal papillæ. Its epithelium is the compound scaly variety like that of the bladder, and is $\frac{1}{600}$ to $\frac{1}{300}$ of an inch thick. The cells frequently contain two nuclei.

Structure of the Kidney.

The kidney is made up of 8 to 15 lobules (pyramids of Malpighi), each inclosed in an investment of areolar tissue; and which are all invested together by the fibrous capsule of the kidney. Outside of

the latter is a layer of loose areolar tissue abounding in fat-cells, improperly termed the *adipose capsule.* The structure of the kidney is, therefore, but the repetition of that of each lobule.

Each lobule is of a pyramidal form, the base presenting on the surface of the kidney, and the apex at the *hilus;* the outer portion, about half an inch thick, being more vascular, and constituting the *cortical* portion of the kidney, while the remaining part contains no Malpighian bodies, but consists principally of the uriniferous tubes, and is termed the medullary or *tubular* portion. The vascular portion, however, also gives off processes inward, extending even to the hilus (the *columns of Bertini*).

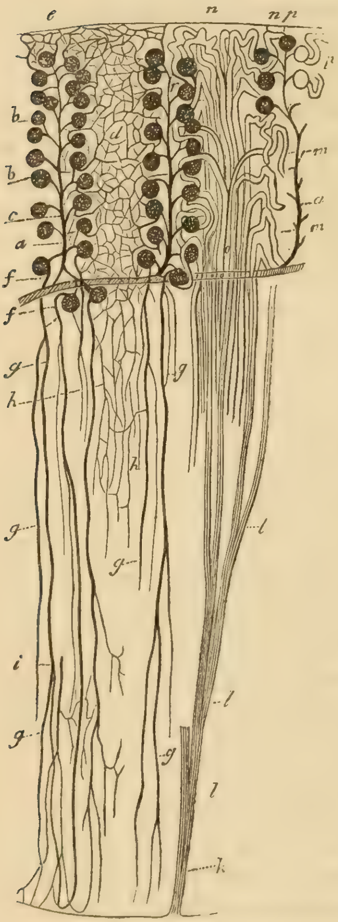
1. The *tubuli uriniferi* of the kidney commence in the papillæ of each lobule (*i. e.* the prominent part constituting the apex of the lobule), by from 200 to 500 orifices $\frac{1}{500}$ to $\frac{1}{120}$ of an inch in diameter, scattered over its surface; and traverse the pyramids in close contiguity (tubes of Bellini). Each tubule in its course divides at least as many as ten times, and usually at very acute angles, into two, or more rarely into three or four smaller branches, diverging from each other, somewhat like the dentinal tubuli; and thus giving a greater diameter to the lobules towards the exterior. Vessels are also interpolated between them at regular distances as they proceed outwards. Arriving in the cortical substance they become curved in their course (*tubuli contorti*), appearing at first sight to be inextricably interwoven, but ultimately terminating, as discovered by Bowman,[1] in a dilated extremity $\frac{1}{1200}$ of an inch in diameter, containing a vascular plexus of a peculiar kind—the *Malpighian body.* (Figs. 375, 130, and 377.)

The *tubuli contorti* (or convoluted portions of the tubes) are, however, actually arranged in columnar masses $\frac{1}{36}$ to $\frac{1}{72}$ of an inch wide (the pyramids of Ferrein), extending through the entire cortical substance; and here they freely anastomose with each other. The number of the tubuli contorti corresponds with that of the Malpighian bodies. Huschke calculates that each "pyramid of Ferrein" contains 200 tubuli, and that there are 700 of these pyramids in a single lobule, or pyramid of Malpighi. Assigning 15 of the latter to each kidney, it would contain 2,100,000 tubuli contorti, and as many Malpighian bodies. Todd and Bowman maintain that the urine is secreted only in these convoluted portions of the tubes. (Figs. 375, *m*, and 130, 1 and 2.)

[1] In 1842.

The tubuli uriniferi are everywhere composed of a simple conoidal epithelium resting upon a strong basement-membrane, $\frac{1}{30000}$ to $\frac{1}{15000}$ of an inch thick, external to which is no distinct corium but merely the stroma, consisting of a firm transparent substance containing small granular cells (*Todd and Bowman*); which, everywhere in the lobule, connects its various structural elements together. (Fig. 376.) Being at the commencement in the papillæ $\frac{1}{500}$ to $\frac{1}{120}$ of an inch in diameter, their branches are soon but $\frac{1}{1200}$ to $\frac{1}{666}$ of an inch; but in the pyramids of Ferrein they again expand to $\frac{1}{600}$ to $\frac{1}{500}$, and in the cortical substance to $\frac{1}{363}$ of an inch or less; though again somewhat constricted just before they end in the dilatation receiving the Malpighian bodies, $\frac{1}{200}$ to $\frac{1}{1200}$ of an inch wide. The nucleated epithelial cells are also larger in the tubuli contorti ($\frac{1}{1500}$ to $\frac{1}{1000}$ of an inch wide, and $\frac{1}{3000}$ to $\frac{1}{2400}$ of an inch thick); while in the straight portion of the tubules they are only one-half as wide, and $\frac{1}{3000}$

Fig. 375.



Vertical section through a portion of a pyramid and the cortical substance belonging to it, of an injected rabbit's kidney. The figure is half diagrammatic. The vessels are represented on the left side, and on the right the course of the tubuli uriniferi. *a.* Arteriæ interlobulares with the Malpighian bodies (*b*), and their vasa afferentia. *c.* Vasa efferentia. *d.* Cortical capillaries. *e.* Vasa efferentia of the outermost bodies, proceeding to the superficial capillaries. *f.* Vasa efferentia of the innermost tufts continuous with the arteriolæ rectæ (*g*, *g*, *g*). *h.* Capillaries of the pyramids which are formed out of the latter. *i.* A venula recta, commencing at the papilla. *k.* Commencement of a straight canal at the papilla. *l.* Divisions of the same. *m.* Convoluted tubes in the cortex, their whole course not shown. *n.* The same at the surface of the gland. *o.* Their continuation in the straight tubules of the cortex. *p.* Their connection with the Malpighian capsules.—Magnified 30 diameters. (*Kölliker.*)

of an inch thick. These cells have also clear, non-granular contents; while those of the tubuli contorti contain, besides the usual

Fig 376.

Section of the cortical substance of the human kidney. A, A. Tubuli uriniferi divided transversely, showing the subconoidal epithelium in their interior. B. Malpighian capsule; *a*, its afferent branch of the renal artery; *b*, its tuft of capillaries; *c*, *c*, secreting plexus (of vessels) formed by its efferent vessels; *d*, *d*, fibrous stroma.

round nuclei, a finely granular albuminous (*Kölliker*) substance in the fluid contents, and generally some dark oil-drops, and more rarely, granules of yellow pigment. (Fig. 132, A & B.) The last cells alone probably secrete the urine. (*Todd and Bowman.*)

2. The *vascular* (cortical) portion of each lobule consists of the tubuli contorti, just described, the Malpighian bodies, the vessels carrying blood to and from the latter, and the stroma of embryonic areolar tissue connecting all these elements together. The *Malpighian bodies* extend to within $\frac{1}{600}$ of an inch of the surface of the kidney on the one hand, and in the *columns* of *Bertini* even to the hilus of the kidney on the other. Each of these is a rounded mass (glomerulus), consisting of a close convolution or tuft of capillaries $\frac{1}{3000}$ to $\frac{1}{1500}$ of an inch in diameter; inclosed in a capsule and supplied by an artery (*vas afferens*), $\frac{1}{1500}$ to $\frac{1}{600}$ of an inch in diameter. This convolution of vessels is received into the dilated extremity of a *tubulus contortus;* and its capsule is apparently the continuous basement-membrane of the tubulus, somewhat thickened. Thus the Malpighian body is virtually inclosed in the extremity of the tubulus; and it amounts to the same thing, practically, if it be said that the tubulus ends like the larger closed extremity of a retort, after having first inclosed the Malpighian body. (Figs. 377, and 131.) A vessel also emerges from the tuft within, through the capsule (the vas efferens)—not a vein, however, as might be expected; the pre-

Fig. 377.

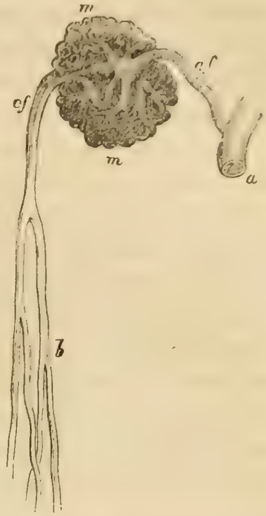
Relations of Malpighian tufts to the arterial branches and the cortical portion of the uriniferous tubes (man). *a*. Arterial branch with its terminating twigs, the injection having only partially filled the tuft at α. It has entirely filled, β, and passed out through the efferent vessel, *e, f*. It has burst into the capsule at γ, entered the tube, *t*, and filled the efferent vessel, *e, f*. At δ it has extravasated, and passed along the tube. At *m* the injection has escaped from the capsule to a limited extent. (Magnified 45 diameters.)

cise arrangement of the vessels being as follows: The artery divides at once on entering the coil into from 5 to 8 branches, and each of these into a bundle of capillaries, which, though much interlaced and convoluted, do not anastomose; and ultimately merge into the *vas efferens* in the way in which they were first formed. Generally, the two vessels enter and quit the glomerulus near together, and opposite the commencement of the tubulus; and the capillary loops and convolutions are always situated exactly at its commencement. The vas efferens after emerging from the capsule of the Malpighian body, proceeds as an artery for a short distance, and then divides into two sets of capillaries—the one going to the cortical portion to encompass the tubuli contorti on all sides in a rich network which is continuous through the whole cortical substance—and the other taking a straight course and with but few branches, between the straight tubes, and in the whole circumference of the pyramids, even to the papillæ, in which they are continuous with the proper capillaries of these parts. (Fig. 378.)

Kölliker describes the epithelium of the tubuli contorti as inclosing the glomerulus; while at the same time the projecting free portion of the glomerulus is covered by epithelium. This has also been recently demonstrated in a very ingenious manner by Dr. Isaacs, of this city; though Todd and Bowman still believe that

the "vessels are bare within the capsule."[1] Kölliker describes the epithelium as existing everywhere between the Malpighian tuft and its capsule, except where the afferent and efferent arteries penetrate. The ciliary motion, described by Bowman, at the junction of the Malpighian bodies and the tubuli contorti, exists in reptiles and fishes; but not in man or other mammalia.

Fig. 378.



Malpighian tuft from near the base of one of the medullary cones. *a*. Arterial branch; *af*, afferent vessel. *m*. Malpighian tuft. *ef*. Efferent vessel; *b*, its branches, entering the medullary cone. (Magnified 70 diameters.)

Vessels and Nerves of the Kidney.

The branches of the renal *artery* enter the cortical substance interposed between the pyramids (columns of Bertini), and in the boundaries of the latter repeatedly dividing, form a delicate ramification without anastomoses around each pyramid. From this on the side towards the cortical substance, smaller arteries arise, mostly at right angles, which, after several divisions, give off the *interlobular arteries* ($\frac{1}{200}$ to $\frac{1}{120}$ of an inch in diameter), which run outwards in a straight course between the cortical fasciculi, or pyramids of Ferrein. And, finally, the last give off on one, two, three, or four sides, a great number of the *arteria afferentia* of the Malpighian bodies already described. Indeed, except a few branches to the capsule of the kidney, all the interlobular arteries terminate in the formation of the vascular tufts. (Figs. 130 and 377.)

The renal *veins* commence in two situations: 1*st*, at the surface of the kidney; and, 2*dly*, at the apices of the papillæ. In the first situation, minute veins are formed from the outermost part of the capillary plexus of the cortical substance, and surround each bundle of Ferrein; and, between the latter, unite in a stellate manner into larger roots, or, extending over several bundles, connect into larger trunks. These, however, all unite to form the *interlobular* veins which accompany the arteries of that name, before described; and

[1] The Physiological Anatomy and Physiology of Man. Part IV., sect. 2, p. 489.

larger branches finally terminate in the wider arched venous ramifications encompassing the pyramids (lobules). The veins of the latter commence in a beautiful plexus surrounding the orifices of the uriniferous tubes on the papillæ, and, ascending with the arteries of the pyramids between the tubuli recti, also terminate in the ramifications just named.

There are, proportionally, but few *lymphatics* in the kidney, accompanying the bloodvessels as far as the interlobular branches.

The *nerves* also (from the cardiac plexus) form a plexus around the arteries, to their interlobular subdivisions. How and where they terminate is unknown.

Of the *chemical composition* of the kidney but little is known. Frerichs found from 72 to 73.70 per cent. of water, and 28 to 26.30 of solid matter. The fat amounted to from .63 to 1 per cent., or even 1.86 (*Owen Rees*); but the greater part of the solid residue is probably albumen from the epithelial cells (p. 114, 1). Dr. Beale finds 76.45 of water, and 23.55 of solid matter; viz., fatty matter containing much cholesterine, .939; watery extractive, 5.84; fixed alkaline salts, 1.01; earthy salts, .396; albumen, vessels, &c., 15.365.

Function of the Kidney.

The kidney secretes the urine; for an account of which see pages 214–22.

It is pretty certain that much of the water in the urine is merely a transudation from the Malpighian bodies; while the peculiar elements of this secretion are secreted by the epithelial cells of the uriniferous tubes, and mainly at least of the contorted portion. It is, however, not probable that a rupture of the epithelial cells is necessary, that their contents may become free in the straight portion of the uriniferous tubes; and hence the same cell may continue to secrete longer than has usually been supposed. (*T. and B.*)[1]

Development of the Kidney.

The urinary passages are developed as an offset from the lower extremity of the intestine; the kidneys being solid at first, like the salivary glands. The tubuli are at first composed solely of a solid series of cells, without any basement-membrane. Subsequently the

[1] Dr. Isaacs, of this city, has recently read a paper before the New York Academy of Medicine, maintaining that the urine is secreted also by the Malpighian bodies. As it is not yet published, we cannot state the grounds of this opinion.

latter appears, and the tubuli become rapidly longer and convoluted. The Malpighian bodies are originally merely the solid thickened extremities of the tubuli, the interior cells of which subsequently become the capillary coil. In the new-born infant, the tubuli are one-third as large as in the adult, and the whole kidney one-half as large. (*Harting.*) Therefore no tubules are formed after birth.

The *suprarenal glands* will be described in connection with the blood-vascular glands (p. 592), since they appear to have no physiological connection with the kidneys.

Pathological States of the Kidney.

1. The *epithelial cells* may contain abnormal contents; *e. g.* an increased amount of fat-drops, constituting fatty degeneration of the kidney (p. 310, 4), with or without pigment-granules; also colloid-like bright-yellow masses are sometimes found in the cells, when they generally dilate into slender cysts, $\frac{1}{240}$ to $\frac{1}{170}$ of an inch long, and which at length burst and discharge the colloid substance into the tubuli, and then into the urine. Cysts may also be formed by partitions of the tubuli contorti, finally separating their extremities from the portions below in the pyramids. The epithelial cells become detached in acute desquamative nephritis.

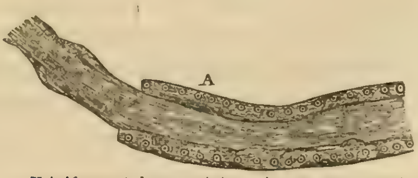
2. The *basement-membrane* sometimes becomes much thickened (to $\frac{1}{12000}$ to $\frac{1}{6000}$ of an inch), and presents close transverse striæ on its inner surface.

3. The *Malpighian* bodies may expand into cysts containing the atrophied glomerulus and a clear fluid.

4. As abnormal contents (p. 215), the *tubuli* may contain blood, fibrine, the colloid substance before mentioned, concretions in the straight tubuli, principally of carbonate and phosphate of lime; and of uric acid salts, in the new-born infant, giving the pyramids a brilliant gold-yellow color. In Bright's disease, exudations into the tubuli first remove the epithelium, after which they become atrophied, or altogether disappear; or become filled with a fatty broken-up exudation, and dilated into minute nodosities or granulations.

5. In *inflammation* of the kidney, the stroma often becomes so much condensed by the exudation as more or less to compress the tubuli. Often, also, the exudation becomes organized into embry-

Fig. 379.



A. Uriniferous tube containing a homogeneous cast.

onic areolar tissue; producing atrophy of the Malpighian bodies by its pressure, and thus interfering with the functions of the gland.

6. The *casts* of the uriniferous tubes, occurring in various conditions of the kidney, have already been noticed (Figs. 123–4, and p. 215). Another form is also shown by Fig. 379.

CHAPTER XV.

THE SEXUAL ORGANS.

I. Sexual Apparatus of the Male.

The male sexual organs are: 1. The testes; 2. The vasa deferentia; 3. The vesiculæ seminales and ejaculatory ducts; 4. The penis, including the urethra and the accessory glands (Cowper's and the prostate). The mucous membrane of the urethra, prolonged through the vesicula seminalis and the vasa deferentia to the seminiferous tubes of the testis, constitutes the *genital passages* of the male.

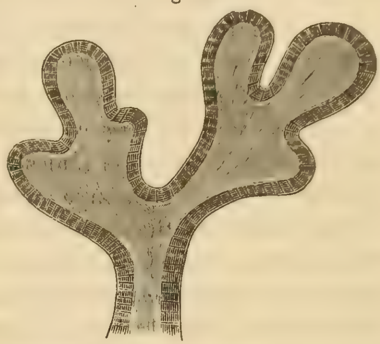
1. The *urethra* is a canal of mucous membrane, supported throughout its spongy portion by the *corpus spongiosum urethræ*, and in the prostatic by the prostate gland; while the membranous portion, so called, is an independent canal. The *corpus spongiosum* is essentially of the same structure as the *corpus cavernosum penis*, next to be described; except that its investing fibrous membrane is much thinner and has more elastic fibres, the intertrabecular spaces are smaller, and the trabeculæ are smaller and richer in elastic fibres beneath their epithelium. It is also invested externally by a layer of smooth muscular fibres, and expands into the glans penis at its free extremity.

The mucous membrane of the prostatic and membranous portions contains smooth muscular fibres, both longitudinal and transverse, though less developed in the membranous portion; and outside of these, in the latter, are the striated fibres of the *accelerator urinæ* muscle. Smooth fibres also exist here and there in the submucous tissue of the spongy portion, and a complete muscular tunic formed of them lies in contact with the corpus spongiosum on its

inside, towards the mucous membrane, and which meets the external muscular layer at the lips of the penis. (*Hancock.*)

The *epithelium* of the urethra is the compound conoidal, consisting of two or three layers of cells. In the anterior half of the fossa Malpighii are papillæ $\frac{1}{400}$ of an inch long, and a scaly epithelium $\frac{1}{300}$ of an inch thick. Racemose mucous glands are found (Littre's glands) in the spongy and membranous portions, of $\frac{1}{36}$ to $\frac{1}{24}$ of an inch (Fig. 380); while in the prostatic portion are minute mucous follicles, like those of the neck of the bladder (p. 542). The epithelium both of the cæca of Littre's glands and of the excretory ducts ($\frac{1}{12}$ to $\frac{1}{16}$ of an inch long) is the simple conoidal, approaching the scaly in the first position. The minute inconstant fossæ of the mucous membrane, called *lacunæ*, contain nothing of a glandular nature. (*Kölliker.*) *Cowper's glands* are also compound racemose mucous glands, and hence have a structure like the salivary glands. The delicate membrane investing them, as well as the fibrous stroma in their interior and their excretory ducts $\frac{1}{48}$ of an inch wide, are well supplied with smooth muscular fibres. A simple conoidal epithelium lines the ducts, and a scaly, the terminal cæca.

Fig. 380.



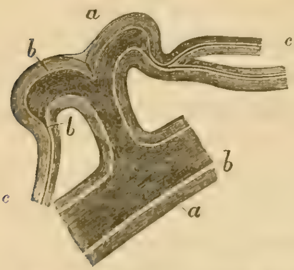
"Gland of Littre," from the fossa Morgagnii in man.—Magnified 500 diameters. (*Kölliker.*)

The *penis* is essentially made up—1*st*, of the urethra, as described, with its spongy body invested by a layer of smooth muscular fibres; and, 2*dly*, the two corpora cavernosa—with its investing fascia, skin, vessels, nerves, &c. The *corpora cavernosa* are two cylindrical bodies rising from the rami of the ischium, and uniting under the symphysis pubis, though there is between them an incomplete septum; and consisting of a special fibrous membrane and the internal spongy tissue. The former is composed of white fibrous tissue with numerous elastic fibres, and is $\frac{1}{24}$ of an inch thick; investing the cavernous bodies externally, and giving off the septum between them, as a thin lamella, partially broken up into separate fibres and laminæ. Within it lies the reddish *spongy* substance, consisting of innumerable fibres, bars, and laminæ, united into a fine meshwork

(the trabeculæ); and the minute rounded angular cavities bounded by the latter, and communicating on all sides. These cavities (the venous sinuses of the cavernous body) are all lined by a delicate scaly epithelium, which often does not admit of being detached; and are naturally filled with venous blood. The trabeculæ are composed of collagenous and elastic tissue in nearly equal proportions, together with smooth muscular fibres; and in many of them larger or smaller arteries and nerves are inclosed. The *fascia penis* incloses the corpora cavernosa from the root of the penis to the *glans*, abounds in elastic tissue, and contributes to the formation of the suspensory ligament of the penis; extending from its dorsum to the symphysis pubis, and containing much elastic tissue. External to this is the subcutaneous areolar tissue, containing a layer of smooth muscular fibres continued from the dartos to the prepuce; and finally the very delicate skin, whose peculiarities, so far as its glands are concerned, have already been specified (p. 487).

The *arteries* of the penis need description here only in regard to the manner in which they supply the *corpora cavernosa*. Very small branches run in a *convoluted* manner, except at the time of erection, in the axis of the trabeculæ, ramify in them, and ultimately open into the venous spaces by ramuscules $\frac{1}{2000}$ to $\frac{1}{1200}$ of an inch in diameter. (Fig. 381, *c*.) In the posterior part of the penis there are numerous minute arterial trunks ($\frac{1}{300}$ to $\frac{1}{150}$ of an inch), lying from 3 to 10 together, and being convoluted in a peculiar tendril-like manner (arteriæ helicinæ); though not terminating in cæcal ends, in most instances certainly, as they were supposed to do by J. Müller. (Fig. 381.) The arterial ramification is precisely similar in the *corpus spongiosum urethræ*. The *veins* commence in the venous spaces, which intercommunicate throughout; from which short efferent veins carry the blood to the superficial ones.

Fig. 381.



Small artery of the corpus cavernosum, giving off a lateral branch dividing into helicine arteries; terminating in very small vessels, which are continued into the trabecular tissue. *a*. Arterial sheath of trabecular tissue. *b*. Wall of the arteries. *c*. Capillary arteries.

The *lymphatics* form very close plexuses in the corium of the glans, and the prepuce, and the remainder of the integument, and communicate with the superficial inguinal glands. There are also lymph-

atics in the *glans* around the urethra, and running backwards on that canal to the pelvic glands.

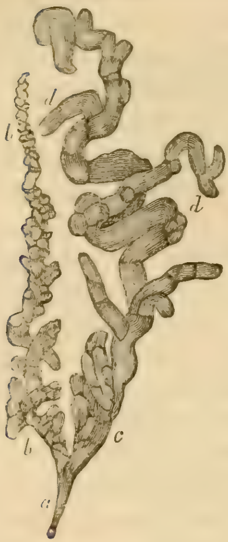
The *nerves* of the penis from the internal pudic, go to the skin and the mucous membrane of the urethra, and, in very small amount, to the corpora cavernosa; while all those from the sympathetic are destined to the latter. The former nerve-fibres terminate like those of the skin generally; of the terminations of the latter, nothing is known.

There is an expansion of the corpus spongiosum of the urethra opposite the root of the penis, called the *bulb* of the urethra; and behind this is the membranous and then the prostatic portion of the urethra—the last being encompassed by the prostate gland.

The *prostate* consists partly (one-third to one-half) of glandular substance, and the rest mainly of smooth muscular fibres. 1. The *glandular* portion consists of 30 to 50 compound racemose glands, generally conical or pyriform, situated principally in the more external parts of the organ. The numerous excretory ducts penetrate between the longitudinal and transverse fibres, and open into the urethra on both sides of the *caput gallinaginis*, which also consists in part of smooth muscular fibres. The cæca of the prostate gland are lined by a simple scaly epithelium; their ducts by a conoidal one. 2. The *muscular* portion of the prostate consists—1*st*, of an external layer of circular fibres continuous with the sphincter vesicæ, extending as far as the *caput gallinaginis;* 2*dly*, of a layer between this and the urethra, composed about equally of areolar tissue and smooth muscular fibres, extending from the vesical triangle to the caput gallinaginis. The fibrous coat which invests the prostate also abounds in fasciculi of smooth muscular fibres.—The secretion of the prostate resembles that of the *vesiculæ seminales*, next to be described.

2 and 3. The *vesiculæ seminales* (Fig. 382), with the ejaculatory ducts, and the vasa deferentia, have essentially the same structure; consisting of an external fibrous tunic, then a layer of smooth muscular fibres, and internally a mucous membrane. The walls of the vesiculæ seminales are much thinner than those of the vasa deferentia; the latter being $\frac{1}{24}$ to $\frac{1}{18}$ of an inch thick, while their whole diameter is $\frac{1}{12}$ to $\frac{1}{9}$ of an inch, and their cavity, or *lumen*, $\frac{1}{48}$ to $\frac{1}{36}$ of an inch. The ejaculatory ducts commence from the prostatic portion of the urethra on each side of the caput gallinaginis, and become continuous on the one hand with the vesiculæ seminales, and on the

Fig. 382.



Vesicula seminalis. *a.* Ejaculatory duct. *b.* Vas deferens. *c.* Vesicula seminalis. *d.* Terminal diverticula. (*E. H. Weber.*)

other with the vasa deferentia. Since the vesiculæ seminales are mere appendages of the vasa deferentia, furnished with saccular or branched processes (Fig. 382), their mucous membrane is also similar; and the last remark may be applied also to the ejaculatory ducts.—The fluid secreted by the vesiculæ seminales is clear, rather viscid, and contains an albuminous compound identical with that contained in the ejaculated semen. Since spermatozoids are so generally contained in it, we must assign to these appendages the double office of secreting a peculiar secretion, and of being a receptacle for the semen.

The *vasa deferentia* have a muscular coat $\frac{1}{31}$ to $\frac{1}{20}$ of an inch thick, consisting of an external layer of longitudinal fibres, a middle one of transverse and oblique fibres, and an internal one, constituting not more than one-fourth of the whole thickness, of longitudinal fibres. The mucous membrane is $\frac{1}{100}$ of an inch thick, yellowish white, longitudinally plicated, and in the widest portions of the canal presents numerous larger and smaller fossæ, disposed in a reticular manner. The deeper two-thirds of the corium is a very closely filled structure of elastic fibres, while the remainder is more transparent. The epithelium is of the simple scaly variety, the cells almost invariably containing some brownish pigment-granules.

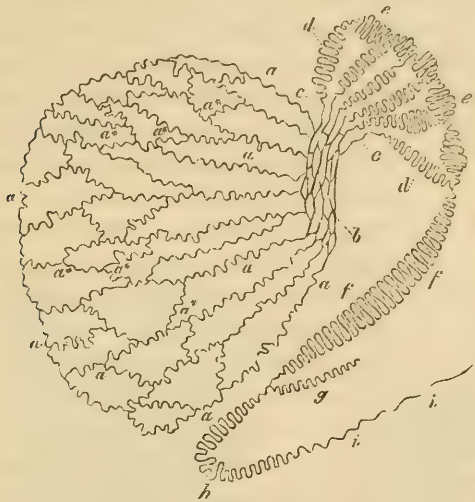
The *vessels* and *nerves* of these three portions of the genital passages require no particular description.

4. The *testes* are glands inclosed in a fibrous tunic (the tunica albuginea), which also sends processes into the interior from a thicker portion called the *corpus Highmorianum.* (Fig. 177.) But for the particulars respecting this and the other tunics, as well as the vessels and nerves, we refer to the works on descriptive anatomy.

The *glandular* substance of the testes consists of 100 to 250 pyriform lobules—not everywhere separated, however—the apices all converging towards the corpus Highmorianum. Each of these lobules is formed of from one to three seminal tubes $\frac{1}{96}$ to $\frac{1}{180}$ of an inch in diameter; which, much convoluted, frequently dividing,

and perhaps also anastomosing, form a compact substance, and terminate at the base of the lobule, either in cæcal extremities or in

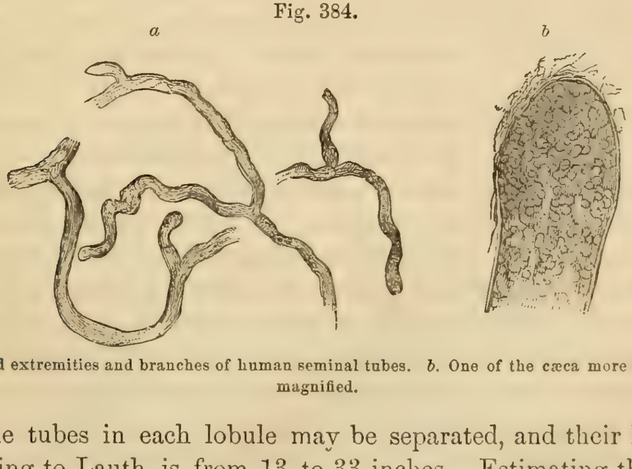
Fig. 383.



Structure of the testis and epididymis. *a, a.* Seminiferous tubes. *a*, a**. Their anastomoses. *a.* Lobules formed of the seminiferous tubes. *b.* Rete testis. *c.* Vasa efferentia. *d.* Flexures of the efferent vessels (cones) passing into the head (*e, e*) of the epididymis. *f.* Body of the epididymis. *g.* Appendix (vasculum aberrans). *h.* Tail of epididymis. *i.* Vas deferens.

loops. (Fig. 383.) Their origin in cæcal extremities is shown by Fig. 384. Though joined together by some areolar tissue and ves-

Fig. 384.

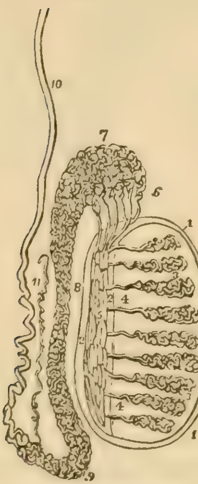


a. Blind extremities and branches of human seminal tubes. *b.* One of the cæca more highly magnified.

sels, the tubes in each lobule may be separated, and their length, according to Lauth, is from 13 to 33 inches. Estimating the average number of lobules in each testis at 175, it would contain from

$189\frac{1}{2}$ to 481 feet of tubing. Out at the apex of each lobule a single tube, $\frac{1}{120}$ of an inch in diameter (tubuli recti), passes into the base of the corpus Highmorianum. These form a very close plexus (the rete testis), from the upper end of which proceed 7 to 15 efferent canals (vasa efferentia testis), $\frac{1}{60}$ to $\frac{1}{72}$ of a line in diameter, which traverse the tunica albuginea, and are continued into the epididymis. Here, contracting to $\frac{1}{96}$ to $\frac{1}{120}$ of an inch, they are convoluted in precisely the same way as in the lobules, but without dividing or anastomosing; and thus form the *spermatic cones*. These, united by connective tissue, constitute the head (globus major) of the epididymis; at the upper and posterior border of which their canals gradually coalesce, and thus a simple duct is formed, $\frac{1}{75}$ to $\frac{1}{60}$ of an inch in diameter. (Fig. 385.) This duct is so convoluted as to form the body and tail (globus minor) of the epididymis; and, after giving off, usually, a cæcal prolongation at its inferior extremity (vas aberrans), is ultimately continuous with the vas deferens, already described.

Fig. 385.



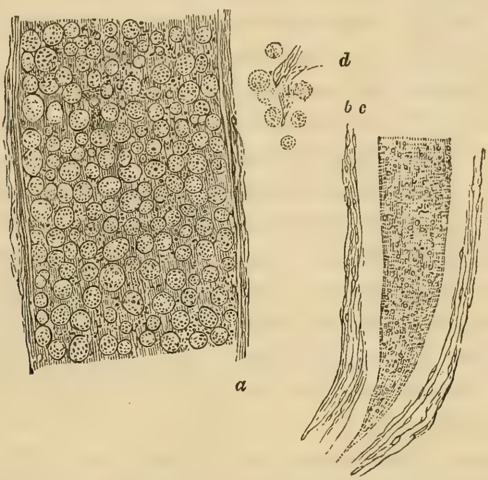
A view of the minute structure of the testis. 1, 1. Tunica albuginea. 2, 2. Corpus Highmorianum. 3, 3. Tubuli seminiferi convoluted into lobules. 4. Vasa recta. 5. Rete testis. 6. Vasa efferentia. 7. Coni vasculosi constituting the globus major of the epididymis. 8. Body of the epididymis. 9. Its globus minor. 10. Vas deferens. 11. Vasculum aberrans, or blind duct.

Structure of the Seminiferous Tubes.

The *tubuli testis* consist of an external fibrous coat, a basement-membrane, and an epithelium, these together being $\frac{1}{1700}$ to $\frac{1}{1200}$ of an inch thick. The first averages $\frac{1}{4000}$ to $\frac{1}{3000}$ of an inch in thickness, is tolerably firm and extensible, contains no smooth muscular fibres, and rarely any indications of elastic tissue. The epithelium is simple conoidal, approaching to the scaly variety. In young subjects the cells are pale and finely granular; but as age increases, a continually increasing quantity of fatty granules is collected in them, giving the seminal tubes a light yellowish, partially brownish color. The tubes in the *rete* testis, however, appear to be mere passages in the dense tissue of the corpus Highmorianum, lined by an epithelium. But in the *cones* the fibrous coat again appears, and to it is added a coat of smooth muscular fibres, continuous upon the vasa deferentia, as before described.

The *contents* of the seminal tubes vary according to age. Previously to puberty, they contain nothing but minute clear cells, resembling epithelial cells. At this period, however, the tubes increase in size, and when the formation of semen has commenced, they become clear, round cells and cysts, $\frac{1}{2400}$ to $\frac{1}{400}$ of an inch in diameter, inclosing from 1 to 10, or even 20, clear nucleolated nuclei, $\frac{1}{5000}$ to $\frac{1}{3570}$ of an inch in diameter. At this time, also, the epithelium is not manifest, the cells in question appearing entirely to fill the tubes (Fig. 386); though at other times, especially

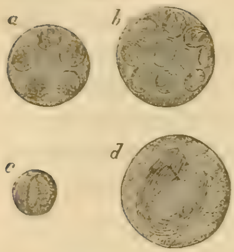
Fig. 386.



Seminal tube (man), with contained cells. *a.* Wall of tube. *b.* Nuclei of fibrous coat. *c.* Basement-membrane. *d.* Cells removed from the tube. The latter figure shows the action of acetic acid. (Magnified 220 diameters.)

in advanced years, the epithelium appears, containing fat, or pigment-cells, surrounding the other elements. The cells and cysts (spermatophori) just mentioned are the precursors of the semen; for in each nucleus a spermatic filament (spermatozoid) is developed on the inner wall, as a spiral corpuscle with two or three turns. (Figs. 387 and 117.) This development commences in the tubuli testis, but it is not completed so that the spermatozoids become liberated, till they reach the rete testis and the coni vasculosi. The nuclei first bursting, the spermatozoids remain for a time in the cysts or spermatophori, the heads and tails together when numerous (10 to 20); but subsequently the spermatophori also burst, in the epididymis, and the dense entangled crowd thus liberated entirely fill its

Fig. 387.



Development of spermatozoids in the spermatophori of the rabbit. *a*. Parent cell with five nuclei. *b*. Each nucleus containing a spermatic filament (spermatozoid). *c*. Nucleus with spermatozoid. *d*. A parent cell with several spermatozoids set free from the nuclei, or cells of development, and coiled together in a bundle.

tubes, some of them still being collected in bundles. The process of development is usually concluded in the lower part of the epididymis, though transitional forms are sometimes found in the vas deferens.

The *pure semen*, as found in the vas deferens, consists of a very small quantity of a viscid fluid, together with the spermatozoids just spoken of; and for a description of which we refer to page 207, and Fig. 116. Semen, *as emitted*, contains the secretions of the vesiculæ seminales, and of Cowper's and the prostate gland, in addition to the two elements before mentioned. The *movements* of the spermatozoids are not exhibited, or slightly if at all, in the pure semen of the vasa deferentia; but are first seen in the less concentrated contents of the vesiculæ seminales.—In the semen of patients who have suffered attacks of double epididymitis, the spermatozoids have remained absent for months, and even years. (*Gosselin.*) In those broken down by seminal losses, they are imperfectly developed, the tails being rough, irregular, and indistinct. (*Lallemand.*) Henle states that the spermatozoids move at the rate of 1 inch in 7½ minutes.

The *ejaculation* of the semen is principally secured by the strong muscular layer of the vasa deferentia, their action being also continued by the vesiculæ seminales, the very muscular prostate, and the layers of smooth muscle inclosing the urethra; to which must also be added the action of the striated muscles, levator ani, accelerator urinæ, &c. The *erection* of the penis is caused, Kölliker maintains, by the relaxation of the smooth muscular fibres contained in the trabeculæ of that organ, and the consequent flaccid state of the venous sinuses and their distension with blood. This is not, however, a satisfactory explanation. The distension of the sinuses of the corpora cavernosa and the corpus spongiosum with blood is, apparently, the immediate cause of erection; this, doubtless, overcoming the contractile force of the smooth muscular fibres in the walls of the trabeculæ for the time being.

II. Sexual Organs of the Female.

The sexual organs of the female are: 1, the vulva; 2, the vagina; 3, the uterus and oviducts; and 4, the ovaries. To these the lacteal glands must also be added.

1. Of the *external* genital organs of the female, together constituting the vulva, the *clitoris* with its two corpora cavernosa and glans, presents, on a small scale, precisely the same conditions as the corresponding parts and corpora cavernosa of the male; the muscular elements being even more readily isolated.

The *mucous membrane* of the vulva has a submucous layer of a spongy, highly vascular, areolar tissue; and a compound scaly epithelium, $\frac{1}{300}$ to $\frac{1}{100}$ of an inch thick. Its *corium* $\frac{1}{48}$ to $\frac{1}{60}$ of an inch thick, is everywhere furnished with much developed papillæ, $\frac{1}{120}$ to $\frac{1}{240}$ of an inch long on the labia minora, and $\frac{1}{288}$ to $\frac{1}{396}$ of an inch on the clitoris. It also contains sebaceous glands on the labia majora (of $\frac{1}{48}$ to $\frac{1}{12}$ of an inch), in connection with hair-sacs; and still more abundantly, and mostly without the latter, on the labia minora, $\frac{1}{120}$ to $\frac{1}{24}$ of an inch in diameter; and sometimes also round the orifice of the urethra, and laterally at the entrance of the vagina. Common racemose mucous glands $\frac{1}{36}$ to $\frac{1}{8}$ of an inch in diameter, with excretory ducts either short, or even $\frac{1}{2}$ an inch long, exist around the orifice of the urethra, in the vestibule and the lateral portions of the entrance of the vagina. The two glands of Bartholini (*Duverney's*), corresponding to Cowper's glands in the male, and situated at the inferior extremity of the *bulbi vestibuli*, are common racemose mucous glands $\frac{1}{2}$ an inch in diameter, with pyriform cæca lined with a scaly epithelium. Their ducts are 7 to 8 lines long, and $\frac{1}{2}$ a line wide, having a longitudinal layer of smooth muscular fibres external to their mucous membrane, and a conoidal epithelium $\frac{1}{1200}$ of an inch thick. The labia majora contain common adipose tissue in their interior.

2. The walls of the *vagina*, $\frac{1}{12}$ of an inch thick, consist of an external fibrous coat, a middle muscular layer, and a mucous membrane. 1. The external tunic is a layer of areolar tissue, containing plexuses of veins, and passing without any line of demarcation into the middle redder layer, consisting of areolar tissue, numerous veins, and some muscular fibres. 2. The latter increase during pregnancy, and becoming $\frac{1}{300}$ to $\frac{1}{150}$ of an inch long, constitute a true muscular membrane. 3. The mucous membrane is pale red,

presents numerous folds and elevations (columnæ), and has a compound scaly epithelium $\frac{1}{171}$ to $\frac{1}{133}$ of an inch thick, like that of the œsophagus; its scales being the largest in the body. Its corium is very firm, and yet very extensible, and presents numerous conical or filiform papillæ (Fig. 389, C), $\frac{1}{200}$ to $\frac{1}{150}$ of an inch in length, and $\frac{1}{500}$ to $\frac{1}{400}$ of an inch broad, which are entirely imbedded in the epithelium. They are very numerous at the lower part of the canal, but diminish towards the *os uteri*. It has no glands at all, except those at the entrance, already described (W. Tyler Smith[1]). The *hymen* is merely a duplicature of the mucous membrane of the vagina, and contains the same elements.

The *bloodvessels* of the vagina and vulva present no striking peculiarities. The *lymphatics* of both are numerous, and communicate partly with the inguinal glands, and partly with the pelvic plexus. The *nerves* derived from the sympathetic and the pudendal branches, are extremely numerous, especially in the clitoris; and are also easily found in the mucous membrane of the vagina, presenting divisions also in both. Kölliker thinks he has also seen loops in the rudimentary axile corpuscles of minute non-vascular papillæ on the clitoris.

3. The *uterus* and *oviducts* (Fallopian tubes) consist of, 1, the peritoneal coat, which presents nothing peculiar; 2, the muscular coat; and 3, the mucous membrane.

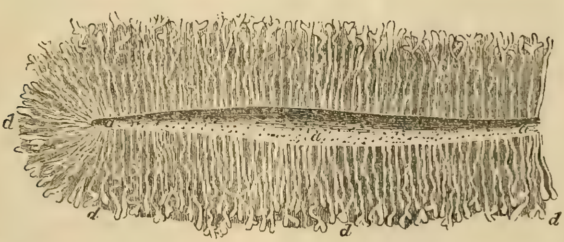
The *muscular* coat of the uterus is pale red, and consists of three layers. 1. The external, is composed of longitudinal and transverse fibres, the former intimately united to the peritoneum, extending over the fundus and the anterior and posterior surfaces of the cervix; while the transverse fibres surround the organ, and to some extent are continued into the round ligaments, and upon the Fallopian tubes. 2. The middle layer is the strongest, presenting longitudinal, transverse, and oblique flat fibres, and containing larger vessels, chiefly veins; whence, especially in the pregnant uterus, it presents a spongy appearance. 3. The inner layer is also formed of slender longitudinal, and stronger transverse and oblique fibres, forming distinct rings at the commencement of the Fallopian tubes. In the *os uteri*, highly developed transverse fibres lie immediately under the mucous membrane constituting an *occlusor* of it (sphincter uteri). All these layers are pervaded by a great quantity of

[1] On the Pathology and Treatment of Leucorrhœa, pp. 20—29.

nucleated embryonic collagenous tissue. In the *Fallopian tubes*, the muscular coat is thicker in the inner half, and consists of external longitudinal, and internal transverse fibres, also mixed with undeveloped collagenous tissue.

The *mucous membrane* of the uterus is whitish-red, $\frac{1}{2}$ to 1 line thick, and cannot be raised from the muscular coat, it is so closely connected with it. Indeed, since the corium so called, also contains smooth muscular fibres, and collagenous tissue without any elastic fibres, it has no clear line of demarcation from the muscular layer underneath. The *epithelium*, everywhere except in the canal of the cervix, and the lower third of the uterine cavity, is the compound conoidal ciliated variety; the cells being $\frac{1}{750}$ of an inch in length, and the cilia vibrating from without to within. In the cavity of the uterus, the corium presents no papillæ, but occasionally a few large folds. It, however, contains numerous minute glands (glandulæ uterinæ), bearing a striking resemblance to the Lieberkühnian glands of the intestines. They extend through the mucous membrane, being $\frac{1}{600}$ to $\frac{1}{400}$ of an inch in diameter, and thickly placed. They are simple or bifurcated, as shown in Fig. 388. Their orifices are even $\frac{1}{360}$ of an inch in diameter; and they are lined by a simple conoidal and not ciliated epithelium.

Fig. 388.



Section of the lining membrane of a human uterus at the period of commencing pregnancy, showing the arrangement and other peculiarities of the glands (*d*, *d*, *d*,) with their orifices (*a*, *a*, *a*,) on the internal surface of the organ. Twice the natural size. (After *E. H. Weber*.)

The mucous membrane of the canal of the *cervix uteri* presents four longitudinal columns of rugæ or folds, the latter being arranged in an oblique, transverse, or curved direction. These columns are separated by four longitudinal grooves, of which those on the median line anteriorly and posteriorly are the most distinct. Sometimes the grooves are replaced by ridges. The two lateral grooves extend through the canal to the angles dividing the anterior and pos-

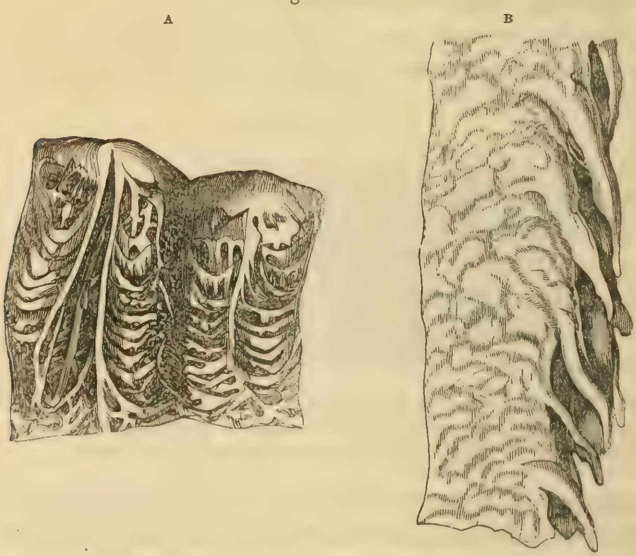
terior lips of the os uteri. Thus two (larger) columns of rugæ correspond to the posterior lip, and two (smaller) to the anterior.

Fig. 389.

Papillæ of vagina and cervix uteri. A. Of the vagina. B. Of the os uteri. C. Of the canal of the cervix uteri. (*W. T. Smith.*)

(Fig. 390.) There are ten to fifteen primary rugæ visible to the naked eye in each column; between which many secondary rugæ,

Fig. 390.



Rugæ of cervix uteri. A. The cavity of a virgin cervix uteri, laid open. Natural size. B. Side view of one of the columns of rugæ and fossæ.—Magnified 60 diameters. (*W. T. Smith.*)

irregularly arranged, appear under the microscope. (Fig. 391.) Other irregular rugæ are also found above, below, and between the columns just described. All these fossæ, thus formed, and which

are improperly termed *follicles*, constitute an "open gland" (*Smith*); and which secretes the clear viscid mucus of the cervix uteri. Here also occur closed vesicles $\frac{1}{3}$ to even 2 lines in diameter (ovula Nabothi), composed of collagenous tissue and a lining of short conoidal cells, and filled with a whitish, pearly coagulated matter, containing glomeruli, cytoid corpuscles, oil drops, and sometimes, also, cholesterine.—They are generally supposed to be merely closed mucous follicles; but since they sometimes occur where no follicles exist, they must, in some cases at least, be a pathological new formation, as cysts very often are in other localities. In the lower third or less, of the canal of the cervix uteri, *i. e.* below the rugæ just described, are verrucose or filiform papillæ $\frac{1}{120}$ to $\frac{1}{40}$ of an inch long, covered with conoidal[1] epithelial cells. (*W. Tyler Smith*, Fig. 389, c). Papillæ only $\frac{1}{4}$ to $\frac{1}{3}$ as large as these, also abound on the os uteri itself. (Fig. 389, B.)

Fig. 391.

One of the four longitudinal columns of rugæ from the virgin cervix.—Magnified 9 diameters. (*W. T. Smith.*)

The mucous membrane of the *oviducts* (Fallopian tubes) is thin, whitish-red, soft, connected to the muscular coat by a small quantity of areolar tissue; and presents no glands nor villi, though it has a few longitudinal folds. From the uterus to the free border of

[1] Kölliker states that these cells are also *ciliated*.

the fimbriæ is a single layer of conoidal ciliated cells, $\frac{1}{2000}$ to $\frac{1}{1200}$ of an inch long, whose cilia vibrate *towards* the uterus—or in a direction contrary to those of the uterine cavity itself. They may aid in the passage of the ovum into the latter; but cannot carry the semen in an opposite direction.

The *round ligaments* of the uterus contain longitudinal bundles of smooth muscular fibres, surrounded by areolar tissue; with which are associated at the internal abdominal ring, many striated muscular fibres, often extending nearly to the uterus. The *ligaments* of the *ovaries* also contain a small amount of smooth muscular fibres; and between the two folds of the peritoneum constituting the *broad ligaments* of the uterus, a small amount of these fibres is continued from the uterus.

Except that the *veins* are large and very thin-walled (uterine sinuses), the *bloodvessels* of the unimpregnated uterus present nothing for special description. The *lymphatics*, probably commencing in the mucous membrane, are very numerous, and proceed in part to the pelvic and partly to the lumbar glands. The *nerves*, from the hypogastric plexus and the pudendal branches, reach the uterus by the broad ligaments, and ramify from the body to the cervix, being most abundant in the latter. Those spread out upon the surface of the uterus are but few in number. (*Dr. Beck.*) They are not in the uterus furnished with any ganglia (*Kölliker*), contrary to the assertion of Dr. Lee, of London; and their condition in the mucous membrane, and their terminations elsewhere, are unknown.

Changes in the Uterus at the Menstrual Period, and in Pregnancy.

At the *menstrual* period the whole uterus enlarges and its texture expands; principally, doubtless, from the distension of its vessels. No change occurs, apparently, in the muscular coat; but the mucous membrane becomes thicker (to 1 or even 3 lines, or in its projecting folds to 5 or 6 lines) and softer, and presents easily isolated uterine glands, 1 to 3 lines long, and $\frac{1}{333}$ to $\frac{1}{300}$ of an inch broad—and many immature round and pyriform cells. The bloodvessels throughout the uterus, and especially of the fundus and the body, are much distended with blood. This is especially the case with the superficial capillary plexus, and hence the bright red color of the mucous membrane. The menstrual *fluid* consists of blood poured out in consequence of rupture of some of these capillaries, with cells of the epithelium, which is in great measure thrown off;

but which is again rapidly restored after the catamenial period has passed (p. 176, E.)

In *pregnancy*, changes of a very different character occur; the increased bulk of the organ being, however, the subject of main interest here. The principal changes occur in the *muscular* structure of the uterus; and these have already been described on page 388. But the *mucous membrane* also undergoes manifold changes; it being also first affected. As early as the second week in pregnancy it becomes 2 to 3 lines thick, is softer, redder, has more prominent *plicæ*, and is more distinct from the muscular coat. The uterine glands become 2 to 3 lines long; and a new formation of areolar tissue has taken place in the corium. These peculiarities become more marked as time advances; and the greater part of the hypertrophied mucous membrane is transformed into the *decidua vera*, while that corresponding to the attachment of the ovum is converted into the *placenta uterina*, and a growth from the border of this produces the *reflexa* around the ovum. No epithelium exists on the decidua after the first month. The mucous membrane of the cervix takes no part in this formation, and retains its epithelium (without cilia), during the whole period of pregnancy.

The *serous* coat of the uterus also increases in thickness during pregnancy, but less than the mucous. The smooth muscular fibres also, and probably the striated, increase in the round ligaments. The bloodvessels and lymphatics also increase in length and calibre, and the nerves appear to become thickened (though it is doubtful whether any new fibres are produced in them), and may be traced further into the organ than at other times.

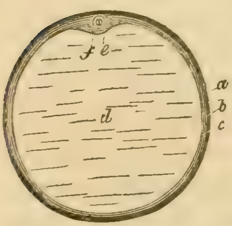
The *return* of the uterus after parturition to a state similar to, but not precisely identical with, its condition previously to that state, is effected (1,) by an atrophy of the muscular structure, so that in three weeks after parturition the fibres are as short as in the virgin uterus (p. 389); and (2,) by the complete removal after parturition of the placenta and decidua, so that the membrane has to be formed anew.

4. The *ovaries* consist of two coats, the peritoneal and the fibrous (tunica albuginea), and the stroma. The last is a grayish-red, tolerably firm substance, composed of embryonic areolar tissue, which contains the ovisacs, or Graafian follicles, and the vessels. The *ovisacs* are entirely closed round cavities ¼ to 3 lines in diameter, and imbedded in the more peripheral parts of the stroma.

There are from 30 to 100 in each ovary, and often even 200; while in old women only 2 to 10, or even none at all, are to be found.

Each mature *ovisac* consists of a *membrane and contents.* The former resembles a mucous membrane, consisting of (1,) a highly vascular fibrous layer (tunica fibrosa), and (2,) an epithelium. Baer distinguished the outer portion of the fibrous layer, which is united to the stroma by a loose connective tissue, from the internal thicker, softer, and reddish portion. The epithelium (*membrana granulosa*), lies upon a basement-membrane, is $\frac{1}{1500}$ to $\frac{1}{1000}$ of an inch thick, lines the whole sac, and on the side of it towards the surface of the ovary, presents a wart-like thickening, the *germinal eminence* (cumulus proligerus). This is $\frac{1}{36}$ of an inch broad, and envelops the *ovum* to be described further on. (Fig. 392.) Its cells are polygonal, with large nuclei and frequently yellowish fatty granules disposed in several layers. (Fig. 145.) The *contents* of the ovisac within the membrana granulosa are (1,) a clear light yellowish fluid of the density of the serum of the blood (*liquor folliculi*); almost always containing (2,) isolated granules, nuclei, and cells detached from the membrana granulosa.

Fig. 392.



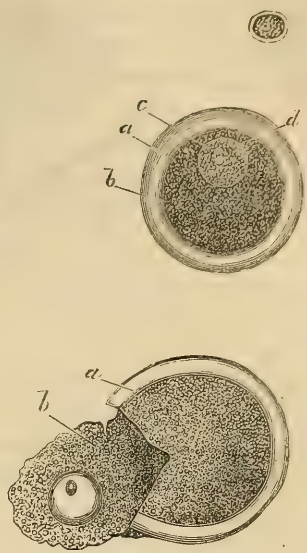
Graafian follicle of the sow. *a*, External, *b*, internal layer of the fibrous membrane of the follicle. *c*. Membrana granulosa. *d*. Liquor folliculi. *e*. Germinal eminence, a projection of the membrana granulosa. *f*. Ovum with a zona pellucida, vitellus, and germinal vesicle.—Magnified about 10 diameters. (*Kölliker.*)

To return to the *ovum*, or egg. This lies close upon the fibrous membrane of the ovisac, on the side of the latter looking to the surface of the ovary, and imbedded in the cells of the germinal eminence before described. When the ovisac bursts, the ovum escapes, completely inclosed by the cells of the eminence and the contiguous portion of the epithelium, constituting the *germinal disk* (discus proligerus). The *ovum* itself is a spherical vesicle, $\frac{1}{96}$ to $\frac{1}{120}$ of an inch in diameter, possessing the nature and constitution of a simple cell, though in some respects peculiar. The cell wall (vitelline membrane), is a simple membrane, is usually $\frac{1}{3000}$ to $\frac{1}{2400}$ of an inch thick, very elastic and firm, and, surrounding the contents as a clear transparent ring, is called *zona pellucida.* (Fig. 393.) The cell is completely filled by the light-yellowish *yolk.* This is a viscid fluid having many minute pale granules dispersed in it, and fatty granules; besides—in the fully

formed ovum—a well-marked vesicular nucleus, the *germinal vesicle.* This is $\frac{1}{600}$ of an inch in diameter with clear contents; and a homogeneous round nucleolus (of $\frac{1}{4000}$ of an inch) on its surface—*the germinal spot.* (Figs. 55 and 393.)

The *arteries* of the ovary enter from its inferior border, and terminate partly in the stroma, and partly in the walls of the ovisacs, where is an inner finer plexus of capillaries extending to the basement-membrane under the membrana granulosa. A few *lymphatics* come out from the *hilus ovarii*, and proceed to the lumbar and pelvic glands. The *nerves* come from the spermatic plexus, and enter the ovary with the arteries. Their ultimate distribution is not yet ascertained.

Fig. 393.



Mammalian ova. Upper figure an immature, and the lower a mature ovum. *a.* Zona pellucida. *b.* Yolk. *c.* Germinal vesicle. *d.* Germinal spot. In the lower figure, the zona pellucida, *a*, is ruptured, and the yolk granules, *b*, and the germinal vesicle have escaped through the opening. (*Coste.*)

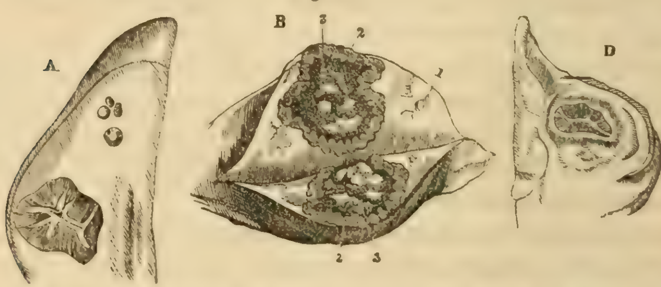
The ovisacs are constantly becoming matured, and then burst as above mentioned, from the commencement of puberty till menstruation ceases; this occurring principally, but not exclusively, at the menstrual period. As they approach the time of bursting, they acquire a diameter of 4 to 6 lines, and at length project beyond the surface of the ovary. Meantime the tunica albuginea and the peritoneal coat become thinner, and at length give way; when the ovum, being situated at the point of rupture as before explained, escapes, surrounded by the germinal disk, and makes its way into the uterus through the Fallopian tube. The empty ovisac is now termed a *corpus luteum.* (Fig. 394.) Occurring in the ordinary course of menstruation they are termed *false corpora lutea;* and *true* corpora lutea, if in connection with impregnation of an ovum. Fig. 395 represents three corpora lutea of pregnancy, at two days and at twelve weeks after delivery and in the sixth week after conception; but a particular description of them is out of place here. The yellow plicated appearance in the interior is due to the thickened condition of the fibrous membrane of the ovisac; and

the contents are the blood poured out upon the rupture of the ovisac, with some remains of its original liquid contents.[1]

Fig. 394.

Human ovary. *a.* Graafian follicle (ovisac) with opening. *b.* Inner lining of follicle (membrana granulosa). *c.* Outer portion of the same. *d.* Ovum. *e.* Vascular wall of ovisac. (*Coste.*)

Fig. 395.



Corpora lutea of different periods. B. Corpus luteum of about the sixth week after impregnation, showing its plicated form at that period. 1. Substance of the ovary; 2, substance of the corpus luteum; 3, a grayish coagulum in its cavity. (After *Dr. Patterson.*) A. Corpus luteum two days after delivery. D. In the twelfth week after delivery. (After *Dr. Montgomery.*)

In respect to the *function* of the female genital organs, it may be here remarked merely that the Fallopian tubes, as well as the uterus and the vagina, manifest *motor* phenomena. The application of the Fallopian tubes to the ovaries to receive the ovum into their fimbriated extremity, is doubtless secured by the action of their mus-

[1] For the most satisfactory account of the corpus luteum, see Prof. J. C. Dalton's Prize Essay, *Transactions of Amer. Med. Association*, vol. iv.

cular fibres. The muscular structure of the uterus may act all at once, or only a part at a time; as during parturition, the os and cervix are at first at rest, while the fundus and body are contracting. In convulsions, the whole uterus contracts firmly round the child (*Kölliker*); in retention of the placenta, the contraction is confined to the *fundus*. The author is convinced that during the orgasm a descent of the uterus, an opening of the os, and a dilatation of the canal of the cervix take place.

The *sensibility* of the interior of the uterus is very slight; careful sounding of its cavity usually causing no pain, and intra-uterine instruments being worn by many patients in the treatment of uterine displacements, with very little inconvenience. The vagina also has but little sensibility internally. The most sensitive parts of the vulva are the clitoris, and the entrance to the vagina at the orifice of the glands of Duverney.

The mucous secretions from the genital passages of the female have already been specified (p. 198). For the changes undergone by the impregnated ovum during its development *in utero*, consult the works on Embryology. The original development of the female genital organs—very analogous to that of the male organs during the first part of embryonic life—will also be omitted here.

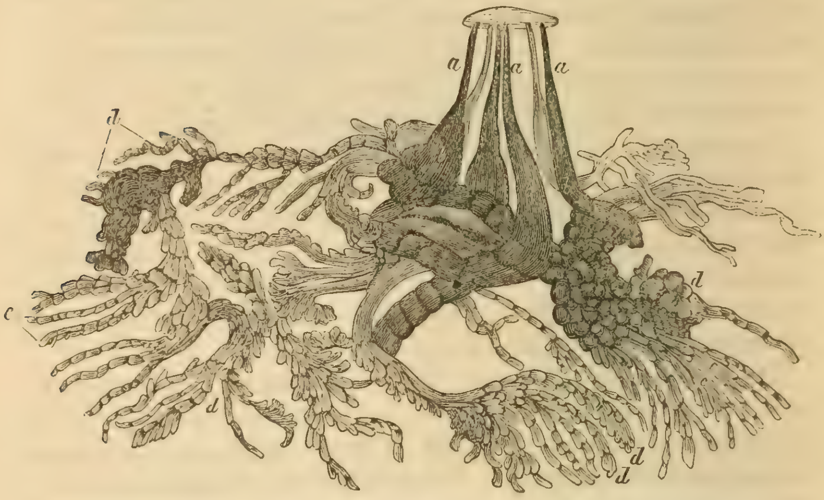
5. *The Lacteal Glands.*

The lacteal glands are of the compound racemose variety, corresponding in all essential particulars with the parotid and the pancreas. Each gland consists of 15 to 24 or more flattened lobes $\frac{1}{2}$ to 1 inch wide, and which are composed of lobules connected by areolar tissue, containing many fat-cells. The terminal cæca of the lobules are rounded or pyriform, and $\frac{1}{240}$ to $\frac{1}{171}$ of an inch in diameter. (Figs. 398, and 115.) The smallest ducts leading from these have a simple scaly epithelium; and these uniting, form the larger trunks. Each of the latter running towards the nipple, dilates beneath the areola into an elongated sac, $\frac{1}{6}$ to $\frac{1}{3}$ of an inch wide;[1] then contracting to 1 or even $\frac{1}{2}$ a line, it bends into the nipple, and finally opens at its apex in a separate orifice, $\frac{1}{36}$ to $\frac{1}{60}$ of an inch in diameter, between the papillæ which exist there. (Figs. 306, 307, 308.) These ducts, about 20 in number, are lined by a so-called mucous membrane, longitudinally plicated in the largest, and, deep in the

[1] These reservoirs in the cow hold even a quart.

gland, containing longitudinal smooth muscular fibres. (*Henle.*) The epithelium is conoidal in the larger ducts, and scaly in the smaller.

Fig. 396.



Six milk-tubes of the lacteal gland, injected from the nipple. *a.* The straight tubes proceeding to the apex of the nipple. *b.* Reservoirs, or dilatations of the ducts. *c.* Branches of the ducts. *d.* Terminal lobules. (*Sir A. Cooper.*)

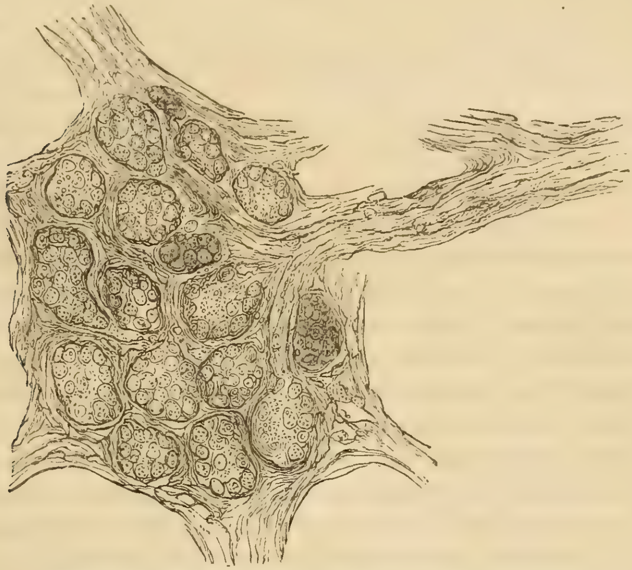
Fig. 397.

Terminal lobule of lacteal gland with ducts; from a puerperal woman.—Magnified 70 diameters. (*Langer.*)

The *nipple* and *areola* contain many smooth muscular fibres (p. 477), and which are much increased in pregnancy. Its compound papillæ are $\frac{1}{120}$ to $\frac{1}{396}$ of an inch long; and their direction is from the base towards the apex of the nipple. The cuticle is not more than $\frac{1}{2000}$ of an inch thick; while the Malpighian layer is $\frac{1}{300}$ of an inch thick, and colored in the deeper portion. Over the gland itself, the papillæ are small and simple, and the epithelium still finer. In the *areola*, but not on the nipple, there are large sebaceous folli-

cles, with fine hairs often visible on the exterior; and sudoriparous glands, often with peculiar contents.

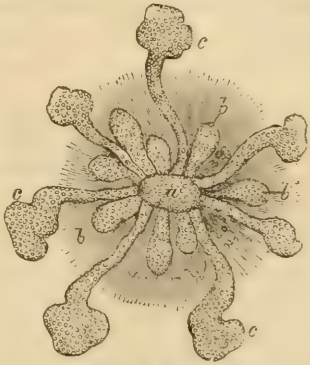
Fig. 398.



Terminal follicles (cæca) of lacteal gland and ducts; from a woman not pregnant. Numerous elastic fibres appear on the wall of the ducts, and the cæca are separated from each other by a considerable amount of areolar tissue. (Magnified 150 diameters.)

The *bloodvessels* present nothing peculiar, except the venous circle in the areola (circulus venosus Halleri).—*Lymphatics* abound in the skin, but are not found in the gland. The same remark also applies to the *nerves*; except that a few fine twigs are found accompanying the vessels.

Fig. 399.



Lacteal gland of a new-born child. The rudimentary follicles are very well shown. (*Langer.*)

The secretion of the lacteal glands, the *milk*, has already been described (pp. 202–5). In their *development* the lacteal follow the same course as the cutaneous glands, being at first merely a solid projection of the stratum Malpighii.

The structure of the lacteal gland in the new-born child is shown by Fig. 399.

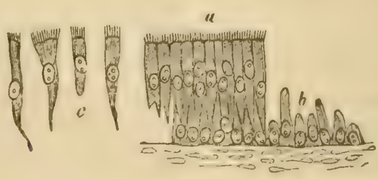
CHAPTER XVI.

THE RESPIRATORY ORGANS.

THE respiratory apparatus consists of the nasal passages; the upper part of the pharynx; the larynx; the trachea; and the lungs. The mucous membrane lining all these constitutes the *air-passages*.

1. The mucous membrane alone of the *nasal passages*, needs to be described here. It is continuous with the skin of the nose at the entrance of the nostrils, and with the mucous membrane of the eye through the lachrymal passages. It is intimately connected with the periosteum of the nasal passages, in the sinuses and some other parts; but on the spongy bones and the septum, forming the direct passages to the pharynx, it is thicker, having a submucous layer of areolar tissue containing plexuses both of arteries and veins. The *corium* presents papillæ resembling those of the skin, just within the nostrils. Its *epithelium* is of the compound scaly variety, like that of the skin, to the distance of about ¾ of an inch within the nostrils, where it becomes the compound conoidal ciliated epithelium, there being two layers of cells (Fig. 400); and

Fig. 400.



Section of the ciliated epithelium of the nasal passages. *a*. Superficial cells clothed with cilia. *b*. Deeper series becoming elongated vertically. *c*. Various shapes of the perfect ciliated cells. (Magnified 180 diameters.)

thus continues through the nasal passages, except over the olfactory region (p. 449). The same epithelium also extends over the upper portion of the pharynx, posteriorly to the level of the larynx, and in front over the posterior surface of the velum—this portion constituting a part of the air-passages, as already stated (p. 522).

This part also of the mucous membrane of the pharynx, abounds in glands. 1. Racemose mucous glands $\frac{1}{36}$ to $\frac{1}{12}$ of an inch in diameter, form a perfectly continuous layer on the posterior wall around the Eustachian tubes, and on the posterior surface of the velum. 2. Closed follicular glands, simple as well as compound, are met with on the vault of the pharynx, where the mucous membrane is closely attached to the base of the cranium. A glandular mass extending from one Eustachian opening to the other, and 1 to 4 lines thick, is constantly found here. This, in aged persons, frequently presents large cavities filled with puriform masses. Other glands also exist upon the sides of the pharynx, and on the posterior surface of the velum, which probably have the same structure as the mucous sacs on the base of the tongue (p. 520).

2. The *larynx* and *trachea*, with the continuations of the latter into the lungs (bronchial subdivisions), resemble in form the excretory ducts of the compound racemose glands, which the lungs may, in fact, be regarded as being. The *larynx* has a framework of cartilages with their connecting ligaments; the thyroid, cricoid, and two arytenoid being true (hyaline) cartilages. The epiglottis, however, and the cartilages of Santorini and Wrisberg, are reticular cartilages (p. 314); and the *cartilago triticea* is common fibro-cartilage. Of the *ligaments*, the middle crico-thyroid, and the inferior thyro-arytenoid (*chordæ vocales*) contain a preponderance of elastic fibres, and are of a yellow color. The other ligaments and the hyo-thyroid membrane, also contain an abundance of this element. To the cartilages and ligaments just mentioned, the striated muscles of the larynx are attached; but which present nothing peculiar to the histologist.

The *mucous membrane* of the larynx, continuous with that of the mouth and pharynx, is smooth and whitish-red, and above the chordæ vocales, has an abundant layer of areolar tissue under it. The membrane is very closely adherent to the vocal cords, and where it lines the larynx below them; and is prolonged into its ventricles. Its *corium* presents no papillæ, and its outer portion abounds in elastic networks. The *epithelium* on the epiglottis is compound scaly, like that of the oral cavity. At its base and above the upper vocal ligaments, commences the compound conoidal *ciliated epithelium*, lining the air-passages throughout. It is here composed of several layers of cells, and is $\frac{1}{500}$ to $\frac{1}{300}$ of an inch thick. The external (*ciliated*) cells are $\frac{1}{800}$ to $\frac{1}{600}$ of an inch long, by $\frac{1}{5000}$

to $\frac{1}{3000}$ of an inch broad, on the average, with elongated round nuclei, and occasionally a few fat-granules. The *cilia* are fine transparent processes of the cell-membrane, $\frac{1}{8000}$ to $\frac{1}{550}$ of an inch long, rising in a broader basis and terminating in a pointed extremity. They have been described on page 243; their motion sometimes continuing 72 hours after death. It should be, however, remarked that the epithelium on the vocal cords is a *scaly*, and not a *conoidal ciliated* one; as discovered by H. Rheiner.

The mucous membrane of the larynx also contains a large number of minute racemose glands ($\frac{1}{120}$ to $\frac{1}{24}$ of an inch), like those of the mouth, pharynx, &c., with cæca lined by a scaly, and ducts by a conoidal, epithelium. They occur sparsely on the posterior surface of the epiglottis. At the entrance of the larynx in front of the arytenoid cartilages, they form a large mass, a horizontal portion of which envelops the cartilage of Wrisberg, while another dips down into the laryngeal cavity. Glands also abound in the external wall of the ventricles of the larynx, behind and above the sacciform ligaments. All these glands secrete pure mucus.

The *bloodvessels* of the larynx are numerous, but require no special description. The numerous *lymphatics* are received by the deep cervical glands. Of the *nerves*, the more sensitive *superior laryngeal* contains more fine fibres; while the *inferior laryngeal* has more thick fibres. (*Bidder*, *Volckmann*). They terminate in the muscles, the perichondrium, and especially in the mucous membrane. The branches going to the *epiglottis* are furnished with microscopic ganglia.

3. The *trachea* contains a series of rings of true cartilage, each completing about $\frac{5}{6}$ of a circle; and between their separated extremities is a transverse layer of smooth muscular fibres. On the outer aspect of this, are isolated longitudinal muscular fasciculi, rising by minute tendons of elastic tissue partly from the inner surface of the ends of the tracheal rings, and partly from the external fibrous membrane; which covers the cartilages as a perichondrium, and at the same time the muscular layer, and connects the different cartilages together.

The *mucous membrane* of the trachea has a layer of close areolar tissue, $\frac{1}{100}$ of an inch thick beneath it, and its *corium* consists of two layers: 1, an external, of areolar tissue, $\frac{1}{100}$ of an inch thick, and, 2, an internal, yellow, $\frac{1}{33}$ to $\frac{1}{120}$ of an inch thick, almost entirely composed of longitudinal elastic fibres. The *epithelium* is

ciliated as in the larynx, and differs in no respect from the latter. The *glands* in the mucous membrane of the trachea are numerous; the larger occurring more in the posterior wall, externally to the muscles and the whole mucous membrane, while the smaller are more numerous on the anterior wall, and just exterior to the elastic layer of the membrane. The larger have a scaly epithelium in their cæca; while the smaller, being only simple or bifurcated follicles in the thickness of the membrane itself, have a conoidal epithelium.

The *bloodvessels* have their larger branches running longitudinally, while the superficial capillary plexus is close beneath the basement-membrane.—The *lymphatics* are abundant; commencing (in one case) in wide meshed plexuses, $\frac{1}{12000}$ to $\frac{1}{4000}$ of an inch broad, of thin-walled vessels giving off cæcal processes. (*Kölliker.*)

4. The *lungs* are, structurally, to be regarded as two compound racemose glands; and an accurate knowledge of the structure of one of the *lobules*, therefore, implies that of a whole lung. The lungs are invested, however, externally, by a serous membrane, the pleura; which, like the peritoneum, forms a closed cavity, and consists of two portions—the pleura *costalis* lining the thoracic cavity, and the pleura *pulmonalis*, directly adherent to the lung. In structure, also, the pleura entirely corresponds with the peritoneum (see p. 523); the parietal layer being the thicker and most adherent, and its epithelium being the simple scaly variety. The pulmonary layer is, however, the more vascular.—*Nerves*, with fine and coarser fibres, are sent to the parietal layer, from the phrenic and the sympathetic (*Luschka*); and Kölliker has seen medium and thick nerve-fibres accompanying the branches of the bronchial arteries in the pleura costalis, and occasionally, large scattered ganglion-cells also.

The *lung proper* consists—1*st*, of the continuations of the trachea (the bronchi and their subdivisions) into the air-cells; 2*dly*, the vessels and nerves; and, 3*dly*, the connective tissue binding all these elements together in the lobules.

1. The *bronchi* and their subdivisions in the lung have the same structural elements as the trachea, on a diminished scale; except that the cartilaginous rings entirely disappear in the finer subdivisions (under $\frac{1}{26}$ of an inch), and in the finest the fibrous tunic coalesces with the mucous. The *smooth muscular* fibres constitute a completely continuous layer in the smaller subdivisions, and terminate $\frac{1}{8}$ of an inch short of the last air-cells to which they lead.

Their appearance in twigs $\frac{1}{120}$ to $\frac{1}{144}$ of an inch in diameter is shown by Fig. 401. Finally the bronchi end in the *lobular passages*.

Fig. 401.

Small bronchial tube laid open, showing the transverse plexiform arrangement of the muscular layer, and its disposition at the orifice of a branch. From a man aged 50. (Magnified 2 diameters.)

The *mucous membrane* lining the bronchi and their subdivisions is at first like that of the trachea, but gradually becomes extremely thin in tubes of less than $\frac{1}{24}$ of an inch. It everywhere consists of a layer of elastic fibres, a basement-membrane $\frac{1}{6000}$ to $\frac{1}{4000}$ of an inch thick, and a ciliated epithelium. The last, even down to tubes 1 line in diameter, contains several layers of cells; but is finally reduced to a single layer of conoidal ciliated cells, $\frac{1}{2000}$ of an inch long. In the larger branches, racemose mucous glands are also found, but these are wanting in tubes of less than 1 to $1\frac{1}{2}$ line in diameter. The subdivisions of the bronchial tubes do not anastomose. The *air-cells* will be described in speaking more particularly of the lobules.

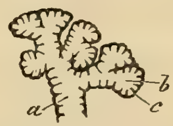
2. The *pulmonary arteries* enter the substance of the lung in company with the bronchi, and follow their subdivisions also, though more frequently dividing dichotomously, and hence more rapidly diminishing in size. Finally, the terminal branches occasionally, but not regularly, anastomosing, merge exclusively into the capillary plexus of the air-cells in each lobule—to be described further on—except a few fine branches to the pleura. (*Henle.*) The pulmonary *veins* rise from this plexus, in radicles more superficial than the arteries, and more external in the smallest lobules; and unite to form larger trunks, proceeding, in great part isolated from the arteries, through the pulmonary substance.—The *bronchial arteries* are distributed—1*st*, to the larger bronchial tubes; 2*dly*, to the pulmonary veins and arteries, as their vasa vasorum (to the latter even $\frac{1}{24}$ of an inch in diameter); and, 3*dly*, to the *pleura pulmonalis*. They do not go to the mucous membrane at all, and do not anastomose with the pulmonary artery or vein.—The *lymphatics* are numerous, but require no distinct description. The bronchial lymphatic *glands* are both numerous, and colored dark brown or black by a carbonaceous deposit. The *nerves*, from the pneumogastric and the sympathetic, are furnished in the interior of the lung with microscopic ganglia, and may be traced nearly to the termination of the

bronchial subdivisions. They accompany the pulmonary artery, and occasionally the veins and the bronchial arteries.

3. The interlobular *connective tissue* of the lungs, everywhere existing very sparingly, is the common areolar, containing in the adult a quantity of *blackish pigment* in the form of irregular minute granules, aggregations of granules, or crystals, but which are never inclosed in cells. They also frequently exist in the walls of the air-cells themselves (p. 132).

The *pulmonary lobules* are far more distinct in the infant and child than in the adult. In the latter, they are so intimately united that even on the surface of the lung their outlines are but imperfectly perceived. They are $\frac{1}{48}$ to $\frac{1}{12}$ of an inch in diameter. The *secondary lobules*, however—$\frac{1}{4}$ to 1 inch in diameter—are very apparent, being bounded by streaks of pigmentary matter.

Fig. 402.

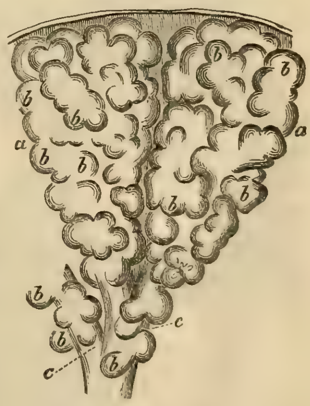


Termination of the bronchi in the lung of the dog. *a.* Terminal tube, and its branches (lobular passages), and the infundibula. *b.* One of the last. *c.* Septa projecting inwards on the infundibular wall, and forming the alveoli or cells. (From *Rossignol.*)

Each lobule is of a more or less conical or pyramidal form, and consists of—A, a terminal bronchial tube; B, the air-cells; and C, the capillary plexus; besides the nerves and some connective tissue.

A. The *terminal air-tubes* are from $\frac{1}{120}$ to $\frac{1}{75}$ ($\frac{1}{60}$ to $\frac{1}{40}$ of an inch—*Todd and Bowman*) of an inch in diameter. They enter at the apex of the lobule, and, passing nearly in its axis, terminate in the lobular passages and infundibula (the former being $\frac{1}{200}$ to $\frac{1}{100}$ of an inch in diameter), as shown in Fig. 402. The air-cells open into the infundibula, and their appearance in the lobule, as seen from without, is shown by Fig. 403.

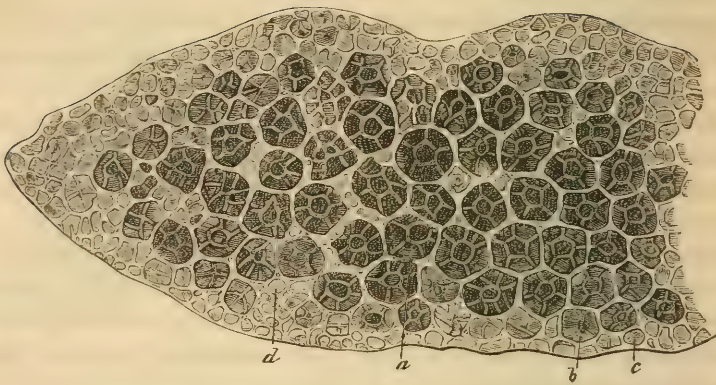
Fig. 403.



Two small pulmonary lobules (*a*, *a*), with the air-cells (*b*, *b*), and the finest bronchial twigs (*c*, *c*); upon which air-cells are also placed. From a new-born child. Half diagrammatic.—Magnified 25 diameters. (*Kölliker.*)

B. The *air-cells* are grouped around and open directly into the infundibula. A few, indeed, open thus into the air-tube before it divides. (Fig. 403.) Thus a honey-comb appearance is afforded by the cells, as seen in their relations

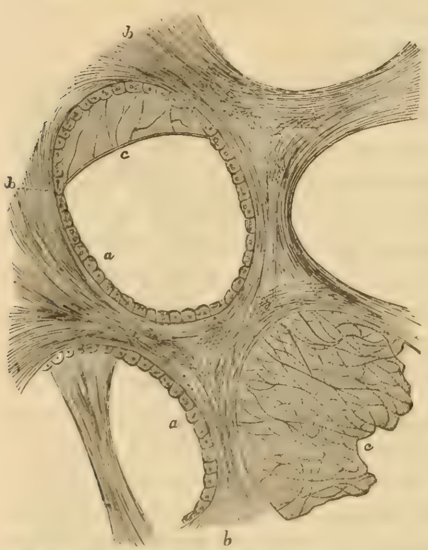
Fig. 404.



Thin slice from the pleural surface of a cat's lung, considerably magnified. At the thin edge (*b*, *c*, *d*), cells (alveoli) are seen. In the centre (at *a*), where the slice is thicker, cells are seen on the walls of infundibula, and opening into the latter. (From *Rossignol.*)

to the infundibula, in sections of the latter. (Fig. 404.) There are about 18,000 air-cells in communication with each terminal air-tube, and the number of cells in both lungs is estimated at 600 millions. (*Rochoux.*) The size of the cells varies considerably; they being after death, and when not distended with air, from $\frac{1}{216}$ to $\frac{1}{72}$ of an inch in diameter. They may, however, be distended to two or three times this diameter without rupturing; and are, probably, at least one-third larger during life than after death. In a collapsed lung, they are usually of a rounded oval form; when inflated, they are rounded angular; and those on the surface of the lung are invariably polygonal, and their external sides almost always plane.

Fig. 405.



Walls of the air-cells. *a.* Epithelium. *b.* Elastic trabeculæ. *c.* Membranous walls with fine elastic fibres.

In *structure*, they present merely a wall (fibrous membrane) and an epithelium. The former has been regarded as the attenuated mucous

membrane and fibrous tunic of the bronchial tubes (*Kölliker*); but it is, in fact, made up of elastic tissue and vessels, in a homogeneous matrix. The elastic fibres present the form, chiefly, of separate trabeculæ and filaments, running between the epithelial linings of the air-cells, and supporting the capillary vessels. (Fig. 405.) By anastomosing with each other, they constitute a firm frame, on which the softer vessels are stretched, while over them the epithelium is laid. These elastic trabeculæ mutually coalesce, so that, for the most part, the boundaries of the separate air-cells cannot be recognized where the latter abut upon each other.

The *epithelium* of the air-cells is the simple scaly variety, composed of pale, polygonal, granular cells, averaging $\frac{1}{2000}$ of an inch in width, and $\frac{1}{3500}$ of an inch in thickness. It lies immediately on the fibrous walls (just described) of the air-cells.

C. The *capillary plexus* of the lobules is one of the closest in the human body, presenting rounded or oval meshes $\frac{1}{6000}$ to $\frac{1}{1500}$ of

Fig. 406.

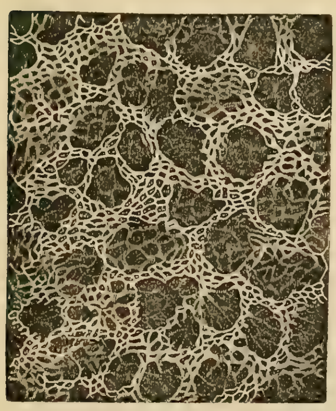


Fig. 407.

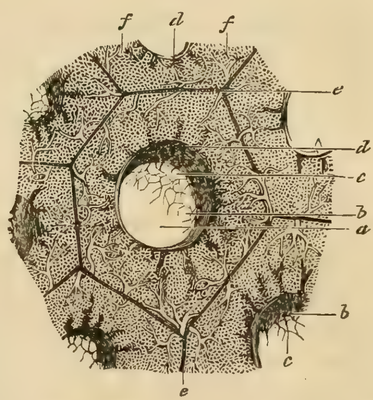


Fig. 406. Arrangement of the capillaries of the air-cells of the human lung.

Fig. 407. Slightly oblique section through a bronchial tube. *a*. The cavity of the tube. *b*. Its lining membrane, containing bloodvessels with large areolæ. *c*, *c*. Perforations in this membrane, where it ceases, at the orifice of the lobular passages, *d*, *d*. *e*, *e*. Spaces between contiguous lobules, containing the terminal pulmonary arteries and veins supplying the capillary plexus (*f*, *f*), to the meshes of which the air gains access by the lobular passages.

an inch wide, and vessels $\frac{1}{4000}$ to $\frac{1}{2400}$ of an inch in diameter.[1] It lies in the wall of the air-cells, about $\frac{1}{12000}$ of an inch from the

[1] Todd and Bowman make the capillaries so large ($\frac{1}{1800}$ of an inch) as to secure a free circulation, and intimate that the blood traversing them moves $1\frac{3}{4}$ inch per minute. Each capillary extends over 8 to 10 air-cells, and the air remains in contact with the blood $1\frac{1}{2}$ second. (*Rainey.*)

epithelium; some of the vessels also projecting fairly into the cells, since they are sometimes thicker than the walls of the latter. It continues not only over all the air-cells of the same lobule, but also anastomoses with the plexuses of the contiguous lobules. A great portion of the capillaries are also situated between, and in relation with, two air-cells at the same time. Fig. 406 shows the capillary plexus seen on the walls of, and between, the air-cells, after the epithelium is removed.—There is also a capillary plexus on the surface of the smallest air-tubes, and even extending to the trachea, in continuation with the preceding, characterized by the elongated form of its meshes (*Heale*[1]), and formed of vessels almost as fine as those of the air-cells ($\frac{1}{3000}$ to $\frac{1}{2400}$ of an inch). (Fig. 407.) Only the pure aerated blood enters this plexus, since it has previously circulated through the capillaries of the air-cells.

Function of the Respiratory Apparatus.

The air-tubes merely conduct the air to and from the air-cells of the lungs. It is not probable that the epithelium becomes desquamated to any considerable extent in disease. At least, it is certain that in croup an exudation may occur through the epithelium without detaching its cells, and which may subsequently be coagulated into a " false membrane," falsely so called, or undergo degeneration into pus (pp. 497 and 189).

The lungs are the *aerating* organs of the blood; *i. e.* they *secrete* carbonic acid gas from the blood in the capillary plexus in the walls of the air-cells, and absorb oxygen at the same time into the blood. The layers interposed between the air in the cells, and the capillary vessels, are but $\frac{1}{2400}$ of an inch thick on an average. The whole amount of surface presented to the air by the six hundred million air-cells in the lungs, has been estimated at 132 square feet, or more than eight times as great as the cutaneous surface of the body;[2] and all the blood in the body traverses the capillary plexus spread out on the air-cells, probably, within the space of two minutes.

Development of the Lungs.

The lungs appear a little after the liver, as two hollow protrusions of the anterior wall of the pharynx; into the composition of which the epithelium and the corium of the pharynx equally enter.

[1] American Medical Monthly, vol. ii. p. 302.

[2] Lindenau computed the whole surface of the air-cells and the air-tubes at 2642 square feet!!!

A continually increasing number of arborescent hollow processes spring from the extremities of the original protrusions, and in the 6th month the air-cells are developed from the dilated extremities. New cells are, however, continually added, up to birth, but not subsequently. Before they are filled with air in the new-born child, they are $\frac{1}{400}$ of an inch, and after breathing, $\frac{1}{300}$ to $\frac{1}{200}$ of an inch in diameter. The subsequent increase of the lungs consists in an expansion of all their parts.

Pathological States of the Lungs.

1. In *emphysema*, the air-cells become permanently dilated to two or three times their normal diameter; or become even ruptured, so that the cells of the same, or even of different lobules, become confluent. Their wall becomes very thin.

The bronchial arteries become dilated in cases where the circulation through the pulmonary arteries is interrupted; the former replacing branches of the latter, and becoming aerating vessels.

2. *Hypertrophy* of the air-cells occurs in hypertrophy of the lungs from increased functional action.

3. The air-cells become *obliterated* by exudation or deposit (*e. g.* tubercular), in the cavities or their walls, or into the interlobular areolar tissue. *Red* hepatization is produced by a complete filling of the air-cells by the exudation of pneumonitis; in *gray* hepatization the walls of the cells and the interstitial tissue become softened, and undergo a fatty metamorphosis. (*Kölliker.*[1])

Fig. 408.

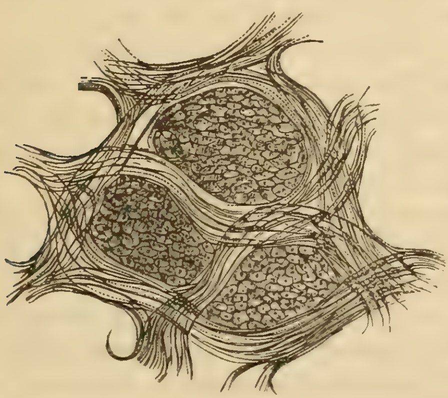


Fig. 409.

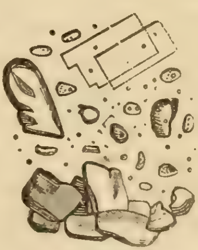


Fig. 408. Section of gray granulations, after addition of acetic acid; showing the air-cells filled with tubercle nuclei.

Fig. 409. Cretaceous transformation of tubercle, with crystals of cholesterine.

[1] See also p. 193, 2.

Deposits of *pigment* occur as a consequence of hepatization, or from a simple congestion of the lungs. Tubercle (gray granulations) is most frequently deposited in the air-cells (Fig. 408); cancer, in the interstitial tissue. The former is liable to cretaceous transformation (Fig. 409).

4. In *œdema* of the lung, serum is effused into the air-cells; in *apoplexy*, blood is extravasated into the interstitial tissue.

5. The epithelial cells undergo a *fatty degeneration* in portions of the lung encompassed by a pleuritic effusion, in atelectasis (*Reinhardt*), and in splenization.

6. *New formations* (bone and cartilage), and cysts, are generally noticed in the interstitial tissue.

7. The parenchyma of the lung is *destroyed* by inflammation, gangrene, tubercle, or cancer; the elastic fibres usually being well preserved, while the remaining elements are infiltrated with fine fatty molecules.

For the pathological states of the *air-passages*, reference may be made to the works on pathological anatomy.

CHAPTER XVII.

THE BLOOD-VASCULAR GLANDS.

This class includes a series of organs possessing a glandular structure, but no excretory ducts; and which are supposed to elaborate substances from the blood to be again applied to some purpose in the organism, after resorption from their tissue. As they derive their designation from a mere hypothesis, it were doubtless better to abolish it altogether. "Ductless glands" (*Todd and Bowman*) is a better designation.

The following organs are referred at the present time to this class; all of which have been described in connection with other parts and organs, except the last four.

The anterior lobe of the pituitary body (p. 465); the solitary follicles of the stomach and intestine, and the aggregated follicles of the small intestine (p. 530); the follicular glands in the root of the tongue, the tonsils, and the pharyngeal follicles (p. 573), and the lymphatic glands (p. 510).

The spleen, the thyroid body, the thymus, and the supra-renal glands—still remain to be described.

I. The Spleen.

The spleen consists of a serous and a fibrous coat, and a soft parenchyma.

1. The *serous coat* is the peritoneal investment, and adheres so firmly to the fibrous coat that it can be dissected off only in fragments.

2. The *fibrous coat* is composed of areolar tissue, and completely invests the spleen, and, at the *hilus*, sends sheaths into the interior around the vessels, like Glisson's capsule.[1]

3. The *parenchyma* is principally composed of (1,) the trabeculæ, inclosing (2,) the pulp, in which (3,) the Malpighian corpuscles are found.

1. The *trabeculæ* are white, shining, flattened or cylindrical bars, averaging $\frac{1}{120}$ to $\frac{1}{36}$ of an inch, of areolar tissue, attached to the inner surface of the fibrous coat, and sometimes to the outer surface of the sheath of the vessels, and which unite to form a network extending through the whole organ. The interstices in it freely communicate, and contain the red pulp and the Malpighian corpuscles. Besides the collagenous and elastic elements, the trabeculæ also contain many peculiar spindle-shaped fibres $\frac{1}{600}$ to $\frac{1}{400}$ of an inch long, and $\frac{1}{6000}$ of an inch wide, with undulated ends and prominent enlargements, containing rounded nuclei. Kölliker at first mistook them for smooth muscular fibres. Their nature is not fully understood. They are sometimes found coiled up in cell-like bodies. (Fig. 410.)

Fig. 410.

Peculiar fibres from the pulp of the human spleen. A. The same, free B. One inclosed in a cell.—Magnified 350 diameters. (*Kölliker.*)

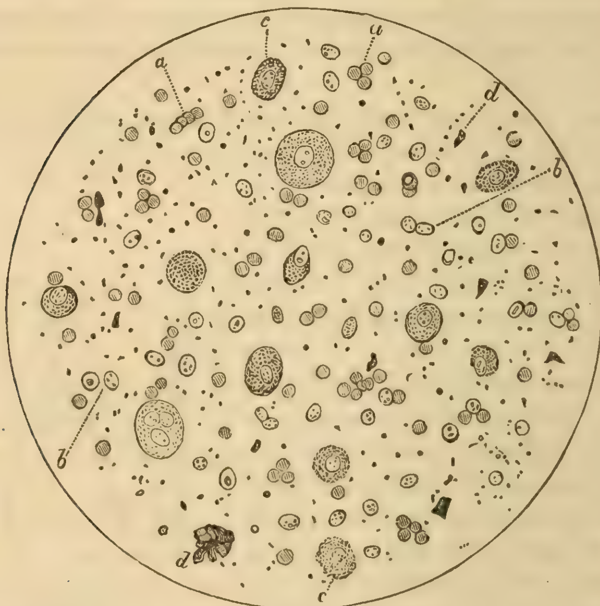
2. The interspaces of the trabeculæ are filled by the *pulp*, in which the Malpighian bodies are lodged. The pulp is a soft, reddish substance, consisting of three elements: 1, the smallest bloodvessels; 2, microscopic fibres and trabeculæ; and 3, peculiar cells. The oc-

[1] In the ox, dog, pig, ass, and cat, it contains smooth muscular fibres also.

currence of extravasated blood in various stages of metamorphosis is also so frequent as to be almost regarded as a normal constituent. The vessels will be described further on. The fine trabeculæ are also composed of areolar tissue, and are $\frac{1}{2400}$ to $\frac{1}{1200}$ of an inch in diameter. The minute fibres are very numerous, and of collagenous tissue; some of them being the terminations of the vascular sheaths.

The *cells* of the pulp (parenchymal cells) (Fig. 411), are round, uni-nucleated, $\frac{1}{4000}$ to $\frac{1}{2400}$ of an inch in diameter, and apparently

Fig. 411.



Pulp of human spleen. *a, a.* Blood-corpuscles. *b, b.* Dotted nuclei. *c, c.* Nucleated vesicles. *d, d.* Colored masses of hæmatine. (*Gray.*)

like those of the Malpighian bodies, soon to be described. More than in the latter also, free nuclei are mixed with them. Pale, round, homogeneous bodies also are found, somewhat larger than blood-corpuscles, resembling free nuclei, or homogeneous nuclei surrounded by a delicate investment; pale larger cells, up to $\frac{1}{1200}$ of an inch in diameter, with one or more nuclei—and cells with dark colorless fat-granules. These elements also exist, but in less extent, in the Malpighian corpuscles. The cells are united by a reddish-yellow fluid; and, together with the latter, constitute about

one-half the mass of the spleen. There are no special investments around these parenchymal cells. They lie in direct contact with the sheaths of the vessels, the trabeculæ, and the sheaths of the Malpighian bodies.

The red pulp of the spleen presents different shades at different times, as they depend on the blood-corpuscles in its vessels; and which present all the various stages of metamorphosis. Kölliker and Gray[1] describe round cells $\frac{1}{2400}$ to $\frac{1}{800}$ of an inch in diameter, holding more or less metamorphosed blood-corpuscles, and containing 1 to 10 or even 20 of them. These, with other masses of corpuscles without an investment, finally become converted into pigment-masses and pigment-cells, after undergoing various changes in color. Finally, however, the last pass into perfectly colorless cells. The more recent investigations, however, of Remak and T. Wharton Jones, throw doubt upon the existence of these red-corpuscle-inclosing cells; especially in the normal state. Reddish crystalline forms (hæmatine) are also occasionally found in the pulp. (*Gray.*)

Fig. 412.

A portion of the splenic artery, its ramifications being studded with Malpighian corpuscles (dog). (Magnified 10 diameters.)

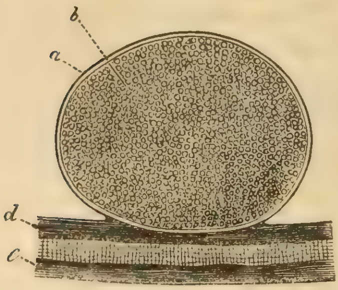
3. The *Malpighian bodies* are white, rounded masses imbedded in the red substance of the spleen, and connected with the smallest arteries.—Kölliker states that they are constant only in healthy subjects, and are found rarely, or not at all, in those dying of disease, or after long fasting. Gray, however, asserts that they are always present in the mammalia, though not always visible to the naked eye. They are $\frac{1}{120}$ to $\frac{1}{36}$ (average $\frac{1}{72}$) of an inch in diameter; being larger after food has been taken. Though imbedded in the red pulp, and hardly separable from it, they are always at-

[1] On the Structure and Use of the Spleen. London, 1854.

tached to an arterial twig, and either rest upon it laterally, or are situated at its angle of division, or transfixed by the artery itself. (Fig. 412.) Arteries of $\frac{1}{600}$ to $\frac{1}{300}$ of an inch have 5 to 10 corpuscles; and each cubic line appears, on an average, to contain one of them (*Kölliker*), they constituting $\frac{1}{8}$ to $\frac{1}{4}$ of the whole pulp. (*Gray.*)

Gray describes the Malpighian bodies as consisting of—1*st*, a closed capsule intimately connected with the sheath of the vessel, formed of simple membrane, and $\frac{1}{12000}$ to $\frac{1}{6000}$ of an inch thick (*Kölliker*) (Fig. 413); and, 2*dly*, its *contents*, a viscid grayish substance, consisting of—1*st*, an amorphous, finely granular matter, containing dispersed nuclei; 2*dly*, nuclei like those of the red pulp, $\frac{1}{3200}$ to $\frac{1}{2000}$ of an inch in diameter; and, 3*dly*, a few nucleated cells, $\frac{1}{2000}$ of an inch in diameter. No blood-corpuscles, either free or in cells, are here met with. Remak and Leidy, however, have not found the distinct capsule above described; but assert that the Malpighian corpuscles pass, in man at least, into the red pulp. The external surface of the closed capsule is covered by a plexus of capillaries. (*Gray.*) Kölliker's idea, of a clear fluid within the capsule, is contradicted by most recent observers.

Fig. 413.



A Malpighian corpuscle from the spleen of an ox. *a.* Wall of the corpuscle. *b.* Contents. *d.* Sheath of the artery. *e.* Wall of the artery.—Magnified 150 diameters. (*Kölliker.*)

Vessels.—The subdivisions of the splenic artery are very numerous, and assume the peculiar arrangement shown in Fig. 412; and finally merge into capillaries $\frac{1}{4000}$ to $\frac{1}{2400}$ of an inch in diameter, constituting a network throughout the pulp and around the Malpighian corpuscles (Fig. 414), and traversing the substance of the latter also. (*Drs. Sanders and Huxley.*) The *veins* present no peculiarity requiring mention here. The *lymphatics* are, comparatively, very few; and the lymph of the deep-seated ones contains blood-corpuscles, perhaps from rupture of minute bloodvessels (p. 148). In diseased spleens, no trace of the superficial lymphatics (those between its two coats) can usually be detected. The *nerves*, consisting of many fine and a few thick fibres, are derived from the splenic plexus, and accompany the branches of the artery into the interior of the organ.

Fig. 414.

The connection of a Malpighian corpuscle with the neighboring vessels. It is placed at the angle of bifurcation of one of the small arteries; its external surface being covered by a close and delicate capillary plexus, while its circumference is invested by a mesh of large veins, radiating from its margin in all directions. The capillary plexus of the pulp is also shown. (*Gray.*)

Function of the Spleen.

Mr. Gray maintains that the spleen regulates both the quantity and the quality of the blood; it being a *diverticulum* of the hepatic circulation, while, at the same time, the Malpighian corpuscles, more especially, elaborate albuminous substances from the blood soon after digestion, store them up for the time being, and again return them to the blood when needed. Though these statements may need some qualification, a comparison of the blood in the splenic veins (p. 175) with that in its artery confirms the idea that the spleen is a blood-making organ, except so far as the colored corpuscles are concerned—these being actually disintegrated in it.

Development of the Spleen.

The spleen is developed, independently of the surrounding organs, at the end of the second month, from a blastema. The Malpighian bodies are last formed, and are much smaller at birth than afterwards.

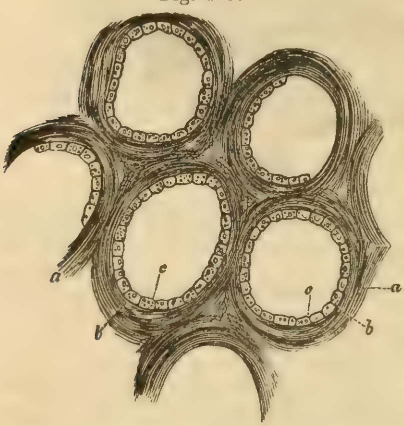
II. The Thyroid Gland.

The thyroid gland consists of closed gland-vesicles $\frac{1}{600}$ to $\frac{1}{240}$ of an inch in diameter, surrounded by a fibrous stroma, and collected into rounded or polygonal lobules $\frac{1}{48}$ to $\frac{1}{24}$ of an inch in diameter, which are associated into lobes; and finally the latter, invested by a fibrous membrane, constitute the whole organ.

Little need be said of the fibrous tissue or stroma, since it is mere common areolar tissue. Only the vesicles need a special description.

The *gland-vesicles* present such varied conditions of structure, that it is not easy to decide what is their normal state. They consist—1*st*, of a basement-membrane lying on the connective tissue between them; 2*dly*, of an epithelium; and, 3*dly*, fluid contents. The basement-membrane is $\frac{1}{15000}$ of an inch thick, and presents no peculiarities. The epithelium consists of a single layer of polygonal, finely granular cells, $\frac{1}{3000}$ to $\frac{1}{2000}$ of an inch in diameter, with simple nuclei. (Fig. 415.) The fluid contained in the cells is clear, somewhat viscous, with a tinge of yellow, and highly albuminous.

Fig. 415.



Some gland-vesicles from the thyroid gland of a child. *a*. Connective tissue between them. *b*. Membrane of the gland-vesicles. *c*. Their epithelium. (*Kölliker.*)

If, however, the organ be changed from its normal state, different conditions are presented. Frequently no epithelium is met with, but only a fluid mixed with minute granules, and free nuclei. The vesicles are also more or less filled with a colloid substance in the form of transparent, amorphous, light-yellowish, soft masses. This, filling the vesicles, transforms the latter into cysts of $\frac{1}{120}$ to $\frac{1}{24}$ of an inch, in which the epithelium is no longer distinct; and which, causing the stroma to disappear by their pressure, ultimately coalesce into larger sinuous cavities. (Fig. 416.)

Fig. 416.

The vesicles of the thyroid gland, filled with colloid matter.—Magnified 50 diameters. (*Kölliker.*)

The following is Dr. Beale's analysis of the thyroid body:—

Water	70.60
Fibrinous and albuminous matter, vessels, and fat	26.384
Extractive matter	1.70
Alkaline salts	.50
Earthy salts	.816

The *bloodvessels* of the thyroid are disproportionally numerous. The terminal arteries are distributed in the stroma between the vesicles, and end in a capillary plexus around each of them, resembling that of the air-cells of the lungs, except that it is less close. The *veins* only partially accompany the arteries, much exceeding them in number. Of the considerable number of *lymphatics*, the relations in the interior are unknown. The few *nerves* contain only vascular nerve-fibres from the cervical portions of the sympathetic. (*Kölliker.*)

The *function* of the thyroid is unknown. It is probably a *diverticulum* to the cerebral circulation; and is developed from an offset from the anterior wall of the pharynx.

Pathological *enlargements* of the thyroid (bronchocele) are very common. These may be due—1*st*, to numerous dilatations of the smaller vessels, the bursting of which may also produce apoplectic cysts, to which fresh extravasations, or exudations and cretification of the vessels may be added; or, 2*dly*, to an actual hypertrophy of the glandular elements, or a production of new gland-vesicles.

III. The Thymus Gland.

The thymus is an organ more especially of fœtal and infantile life. It consists of lobules grouped around a central canal, which is generally spirally convoluted. The lobules are collected into lobes; while the latter, invested by areolar tissue, constitute the whole organ.

The lobules are, however, composed of smaller hollow subdivisions, and the latter of rounded corpuscles, like gland-vesicles, which give the exterior of the lobules a delicate mosaic aspect, not unlike that of the lungs. (Fig. 417.) These corpuscles are, how-

Fig. 417.

A section of the thymus gland at the eighth month, showing its structure; from a preparation of Sir A. Cooper. 1. The cervical portions of the gland; the independence of the two lateral glands is well marked. 2. Secretory follicles seen upon the surface of the section; these are observed in all parts of the section. 3, 3. The pores or openings of the secretory follicles and pouches are seen covering the whole internal surface of the great central cavity reservoir. The continuity of the reservoir, in the lower or thoracic portion of the gland, with the cervical portion, is seen in the figure.

ever, not vesicles, but solid bodies, cohering intimately towards the cavities, though separated from each other on the outer side.

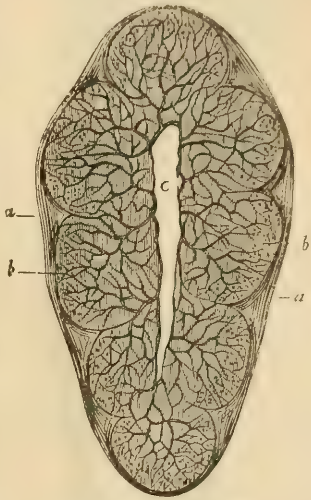
Each lobule is inclosed in a thin, almost homogeneous, membrane, $\frac{1}{24000}$ to $\frac{1}{12000}$ of an inch thick. Within this, and between it and the *cavity* of the lobule, lies a grayish-white soft substance, $\frac{1}{72}$ to $\frac{1}{36}$ of an inch thick, consisting of free nuclei and minute cells, among which bloodvessels and a small amount of white fibrous tissue are sent; and thus a structure is presented resembling that of the contents of the follicles of Peyer (p. 530).

The cells and nuclei, however, of the thymus-lobules, with a small quantity of a connecting fluid, constitute the main bulk. The

cells are much less numerous than the free nuclei, and from $\frac{1}{3000}$ to $\frac{1}{1200}$ of an inch in diameter; the latter being $\frac{1}{8000}$ to $\frac{1}{2400}$ of an inch.

The *arteries* (Fig. 418) are sent from the external surface through to the internal cavity, and there ramify in a delicate expansion of areolar tissue lining it. From this arterial plexus, branches enter the cavity of each *lobule*, and form a capillary plexus in their external portion, or the gland-corpuscles, entirely filling them, but never extending further than to the inner surface of the homogeneous membrane investing them.—The fibres above mentioned support the capillaries just described, and require no special description.—The *lymphatics* are numerous; and *nerves* accompany the arteries, though not yet traced to their terminations.

Fig. 418.



Transverse section of an injected lobule of the thymus of a child. *a*. Membrane of the lobule. *b*. Membrane of the gland-corpuscles. *c*. Cavity of the lobule from which the larger vessels branch out into the corpuscles, on the surface of which they terminate, occasionally forming loops. (30 diameters.)

The *cavities* of the thymus inclose a grayish-white or milky, faintly acid, albuminous fluid, containing numerous nuclei, isolated cells, and sometimes concentric corpuscles, next to be described.

Between the ages of 12 and 20 years, involution of the thymus commences. During this, peculiar spherical bodies are found in the substance of the lobules, called the *concentric* corpuscles. These (first noticed by Hassall and Virchow) are: 1. *Simple*, $\frac{1}{2000}$ to $\frac{1}{1200}$ of an inch in diameter, with a thick concentrically striated membrane and a granular substance within, appearing sometimes as a nucleus, at others as a cell; 2. *Compound*, $\frac{1}{300}$ to $\frac{1}{150}$ of an inch in diameter, and consisting of several simple corpuscles inclosed in a common laminated envelop. By the 40th year, the thymus is usually entirely removed.

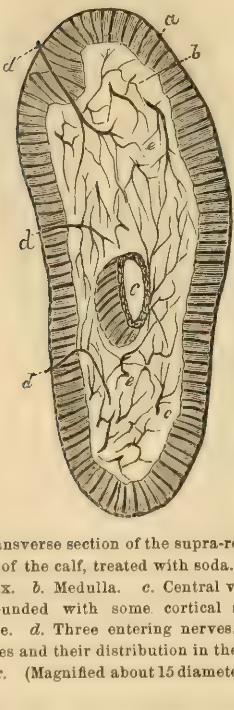
The *function* of the thymus is not certainly known. Mr. Simon considers it "a sinking fund in the service of respiration." It is developed by two tubular offsets from the larynx, containing blastema. It is not stationary after birth, as sometimes stated, but grows

considerably up to the 2d year. Subsequently it becomes atrophied, and finally disappears, as above mentioned.

IV. The Supra-Renal Glands.

These bodies are usually classed with the blood-vascular glands, though they do not strictly belong to this class. They consist (1,) of a fine, but thin coat of areolar tissue, and (2,) the proper parenchyma. The former needs no special description.

Fig. 419.



Transverse section of the supra-renal body of the calf, treated with soda. *a.* Cortex. *b.* Medulla. *c.* Central vein, surrounded with some cortical substance. *d.* Three entering nerves. *e.* Nerves and their distribution in the interior. (Magnified about 15 diameters.)

The *parenchyma* is divisible into two parts, the cortical and the medullary portions. (Fig. 419.) 1. The *former* is of a whitish-yellow color (more nearly brown in its innermost third), $\frac{1}{36}$ to $\frac{1}{24}$ of an inch thick; easily torn in the direction of its thickness, and when torn, presenting a fibrous aspect.

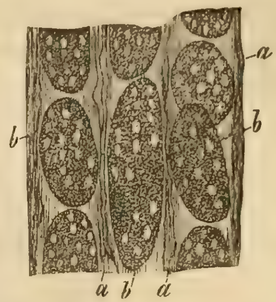
2. The *medullary* substance is of a brighter color than the cortical, being grayish-white with a tinge of red, though it may become darker when its veins are full of blood. It is softer than the cortical substance, and only $\frac{1}{72}$ to $\frac{1}{36}$ of an inch thick at their borders; while it is 1 to $1\frac{1}{2}$ line in the middle, and the lower and inner half of these organs.

In their *intimate* structure the cortical and the medullary portions are entirely *dissimilar*. The *cortical* substance consists of very numerous compartments (cortical cylinders, *Kölliker*), $\frac{1}{750}$ to even $\frac{1}{400}$ of an inch across, formed by interlacements of areolar tissue, and extending through the entire thickness of the cortex; containing a granular substance, subdivided by delicate, oblique, or transverse dissepiments. (Fig. 420.) These generally contain nothing but rounded angular cells, $\frac{1}{2000}$ to $\frac{1}{1000}$ of an inch in diameter. In the inner brown layer of the cortex, the cells are entirely filled with brown pigment-granules.

The *medullary* substance also has a stroma of areolar tissue pro-

longed from the cortical lamellæ, and pervading the whole interior, forming a network with rather wide meshes. This is filled by a pale, finely granular substance, containing pale cells, $\frac{1}{1500}$ to $\frac{1}{750}$ of an inch in diameter, resembling the nerve-cells of the central organs, though they cannot be definitely declared to be such. (*Kölliker.*)

Fig. 420.



Portion of a vertical section through the cortex of the supra-renal body in man. *a.* Septa of connective tissue. *b.* Cortical cylinder whose composition from cells is more or less distinctly manifest. (Magnified 300 diameters.)

The *bloodvessels* of the supra-renal glands are very numerous. Sometimes even twenty arterial trunks enter one of these glands. A capillary plexus with elongated meshes exists in the cortical substance, and one with rounded interstices in the medullary. Thus the cortical cylinders are surrounded by blood on all sides; and this capillary plexus joins that of the medullary substance, formed principally by arteries penetrating at once into the latter. A few *lymphatics* are found on the surface of the organ, but more in its interior.

The *nerves* of the supra-renal glands are very numerous; being derived from the semi-lunar ganglion, and the renal plexus; and also, to a small extent, from the pneumogastric and the diaphragmatic. (*Bergmann*). Kölliker has counted 33 trunks entering the right supra-renal gland, varying from $\frac{1}{60}$ to $\frac{1}{600}$ of an inch in diameter; and found that almost without exception, they were constituted of dark-bordered, finer, and medium-sized, or even thick, nerve-fibres; and were furnished with isolated larger or smaller ganglia. They appear to be all destined for the medullary substance, where there is an extremely rich nervous plexus; the terminations of the fibres being, however, nowhere perceptible.

The supra-renal glands are *developed* simultaneously with the kidneys, but independently of them; and are originally larger than they. The first appearance and growth of the blastema where they are found is unknown.

Of the *function* of the supra-renal glands, nothing positive is known. They, however, have pretty certainly no physiological connection with the kidneys. Kölliker thinks that while the cortical portion may belong to the class of blood-vascular glands, the

medullary portion is physiologically distinct from the former, and must be regarded as an apparatus pertaining to the nervous system, as Bergmann suggested. And Leydig's recent investigations in regard to the structure of these organs in fishes and reptiles, have led him to conclude that they have the same relation to the ganglia of the sympathetic nerves, that the pituitary body bears to the brain (p. 465).

CHAPTER XVIII.

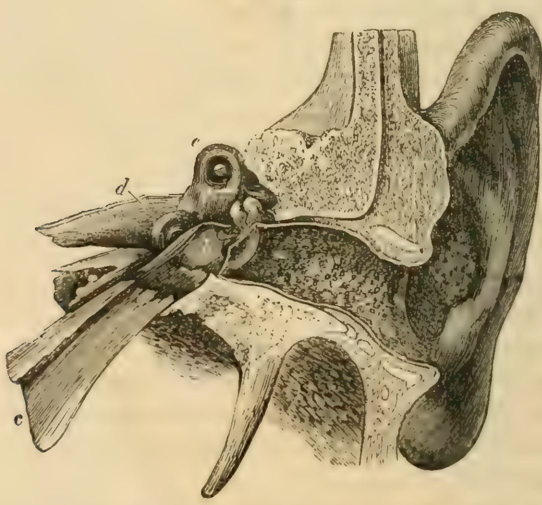
THE ORGANS OF THE SENSES.

THE histological elements of the organs of the senses have already been mostly described.

I. The organ of *touch*—the skin—in Chap. XI. (pp. 476—494.)

II. The organ of *taste*—the mucous membrane of the tongue—pp. 515–18, and Figs. 344 to 347.

Fig. 421.



General view of the external, internal, and middle ear, as seen in a prepared section through *a*, the auditory canal; *b*, the tympanum or middle ear; *c*, Eustachian tube, leading to the pharynx; *d*, cochlea; *e*, semicircular canals, and vestibule, seen on their exterior as brought into view by dissecting away the surrounding petrous bone. The styloid process projects below; and the inner surface of the carotid canal is seen above the Eustachian tube. (From *Scarpa*.)

III. The organ of *smell*—the olfactory nerves and the mucous membrane of the nasal passages—p. 448, and Figs. 290–2.

IV. The organ of *hearing*—so far as the acoustic nerve, and the distribution of its cochlear branch are concerned—has been described on p. 453, Figs. 300 and 301.

Fig. 422.

The soft parts of the vestibule taken out of their bony case, so as to show the distribution of the nerves in the ampullæ. 1. The superior semicircular membranous canal or tube. 2. The external semicircular tube. 3. The inferior semicircular tube. 4. The tube of union of the superior and inferior canals. 5. The sacculus ellipticus. 6. The sacculus sphericus. 7. The portio dura nerve. 8. The anterior fasciculus of the auditory nerve. 9. The nerve of the sacculus sphericus. 10, 10. The nervous fasciculi to the superior and external ampullæ. 11. The nerve to the sacculus ellipticus. 12. The posterior fasciculus of the auditory nerve furnishing (13), the filaments of the sacculus sphericus, and 14, the filaments of the cochlea, cut off.

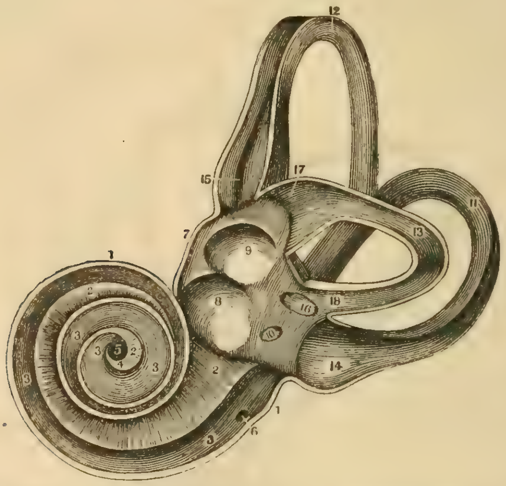
Fig. 423.

The ampulla of the external semicircular membranous canal, showing the mode of termination of its nerve.

A section of both the external and internal ear is shown by Fig. 421.

The membranous labyrinth, and the terminations of the vestibular nerve, are shown by Figs. 422, 423.

Fig. 424.



A view of the labyrinth of the left side, laid open in its whole extent so as to show its structure. Magnified about 12 diameters. 1. The thickness of the outer covering of the cochlea. 2, 2. The scala vestibuli, or upper layer of the lamina spiralis. 3, 3. The scala tympani or lower layer of the lamina spiralis. 4. The hamulus cochleæ. 5. Centre of the infundibulum. 6. Foramen opening into the tympanum. 7. The thickness of the outer layer of the vestibule. 8. The foramen rotundum. 9. The fenestra ovalis. 10. The orifice of the aqueduct of the vestibule. 11. The inferior semicircular canal. 12. The superior semicircular canal. 13. The external semicircular canal. 14. The ampulla of the inferior canal. 15. The ampulla of the superior canal. 16. The common orifice of the superior and inferior canals. 17. The ampulla of the external canal.

Fig. 425.

An anterior view of the external ear, as well as of the meatus auditorius, labyrinth, &c. 1. The opening of the ear at the bottom of the concha. 2. The meatus auditorius externus, or cartilaginous canal. 3. The membrana tympani stretched upon its ring. 4. The malleus. 5. The stapes. The labyrinth.

The whole labyrinth (internal ear), consisting of the cochlea and semicircular canals, laid open, is shown by Fig. 424. Its relations to the external and middle ear are seen in Fig. 425.

V. The Eye.

Some of the structural elements of the eye have already been spoken of (pp. 449–53); and the rest will be described here.

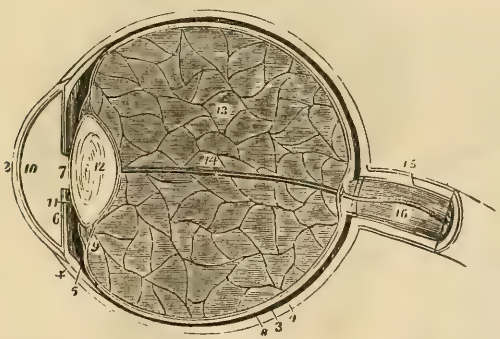
I. *Membranes of the Eye.*

A section of the eyeball is shown by Fig. 426. The three membranes of its posterior seven-eighths, or more, are the tunica sclerotica, the choroid, and the retina; while the cornea is seen projecting in front, and the iris is represented by 6, in the figure.

1. The *sclerotic* coat is composed of white fibrous tissue and a few elastic fibres (p. 279); and is shown, together with the choroid, by Fig. 427.

2. The *choroid* coat is continuous in front with the iris; a narrow ring of white fibrous tissue—the *ciliary ligament*—connecting them

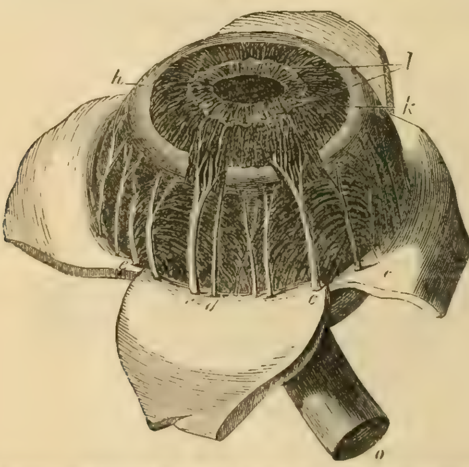
Fig. 426.



A longitudinal section of the globe of the eye. 1. The sclerotic, thicker behind than in front. 2. The cornea apparently received within the anterior margin of the sclerotic, and connected with it by means of a bevelled edge, though really continuous with it. 3. The choroid, connected anteriorly with (4), the ciliary ligament and (5), the ciliary processes. 6. The iris. 7. The pupil. 8. The third layer of the eye, the retina, terminating anteriorly (ora serrata) at the commencement of the ciliary processes. 9. The canal of Petit, which encircles the lens (12); the thin layer in front of this canal is the zonula ciliaris, a vascular prolongation of the retina to the lens. 10. The anterior chamber of the eye containing the aqueous humor; the lining membrane by which the humor is secreted is represented. 11. Posterior chamber. 12. The lens more convex behind than before, and inclosed in its proper capsule. 13. The vitreous humor inclosed in the hyaloid membrane, and its cells formed in its interior by that membrane. 14. A tubular sheath of the hyaloid membrane, which serves for the passage of the artery of the capsule of the lens. 15. Perineurium of the optic nerve. 16. The arteria centralis retinæ, imbedded in its centre.

firmly at their union, with the sclerotica. (Figs. 427–8.) The choroid itself is essentially a thin lamina of capillaries, with arteries and veins external to it, and lined on its internal surface by a single layer of nucleated pigment-cells of a pentagonal or hexagonal shape. (Fig. 69.) Between the capillary network and the arteries and veins, as well as among the veins themselves, there is also an abundance of pigment-cells. The internal plexus of capillaries is termed the *tunica Ruyschiana.* (Fig. 429.) The *veins* of the choroid are arranged in beautiful curves, and are termed *vasa vorticosa.* For $\frac{1}{8}$ of an inch behind the ciliary ligament, the choroid coat is separated from the sclerotic by the *ciliary muscle*, consisting of smooth muscular fibres. (Fig. 428.) The last is covered externally by the ciliary processes, which are projecting folds of the choroid, lodged in similar folds upon the vitreous body—the *ciliary zone.* They also are very vascular (Fig. 430), and contain an abundance of irregular pigment-cells. The *ciliary nerves* are seen on their way to the iris in Fig. 427.

Fig. 427.



Choroid and iris exposed by turning aside the sclerotica. *c, c.* Ciliary nerves branching in the iris. *d.* Smaller ciliary nerve. *e, e.* Vasa vorticosa. *h.* Ciliary ligament and muscle. *k.* Converging fibres of the greater circle of the iris. *l.* Looped and knotted form of these near the pupil, with the converging fibres of the lesser circle of the iris within them. *o.* The optic nerve. (From *Zinn.*)

3. The *retina* has already been described (pp. 450–3, and Figs. 295 to 299). The relations of the crystalline lens and the vitreous body are shown by Fig. 431.

4. The *cornea* has already been described at length (pp. 280–1, and Figs. 178 to 180).

5. The *iris* is a process of the choroid, and continuous behind with the ciliary processes; though modified in structure. For it

Fig. 428.

Fig. 429.

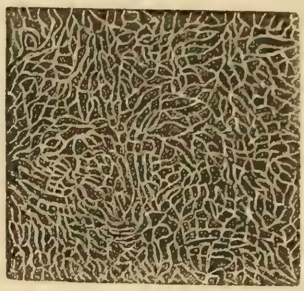


Fig. 428. Diagram to show the position and action of the ciliary muscle. *a.* Sclerotic. *b.* Cornea. *c.* Choroid, separated a little from the sclerotic. *d.* Situation of the ciliary ligament, and point from which the ciliary muscle radiates. *e.* Iris. *n.* Lens connected with the ciliary processes of the anterior wall of the canal of Petit, the situation of which is marked by the *. (Magnified 3 diameters.)

Fig. 429. Capillary network in choroid coat of the eye.

has, 1, a *stroma*, mostly of collagenous tissue; 2, smooth muscular fibres; and 3, a layer of cells on both its anterior and its posterior surface. The *muscular fibres* form (1,) a distinct occlusor of the pupil (*sphincter pupillæ*) in the form of a smooth ring $\frac{1}{48}$ of an inch wide, close to the edge of the iris. There is, besides, another very narrow ring $\frac{1}{480}$ of a line wide. (2.) They also form numerous slender fasciculi, but not a distinct layer, extending from the outer margin of the iris to the *sphincter pupillæ*, into the border of which they are inserted, constituting the *dilator pupillæ*.

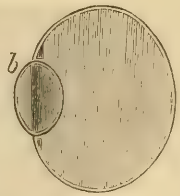
The layer of *cells* on the posterior surface of the iris, constitutes the *uvea;* they being closely filled pigment-cells. The anterior layer of cells is a simple scaly epithelium without pigment-granules.—The *color* of the iris in blue eyes depends merely upon the pigment in the *uvea*, seen through the substance of the iris; in hazel

Fig. 430.

Vessels of the choroid, ciliary processes, and iris; inner surface. *a.* Portion of the capillary network, or tunica Ruyschiana. *b.* Ciliary processes. *c.* Portion of the iris. From an infant. (After *Arnold*.—Magnified 14 diameters.

and black eyes, the pigment also exists in the stroma and among the other elements of the iris itself.

Fig. 431.



Position of the lens (*b*) in the vitreous humor, shown by an imaginary section. The dark triangular space on each side of the lens is intended to indicate the position of the canal of Petit.

The bloodvessels and the nerves of the iris are numerous. The ciliary branches of the latter are shown by Fig. 430.

II. *Humors of the Eye.*

The three humors of the eye are the crystalline lens, and the vitreous, and the aqueous humor. Fig. 431 shows the relation of the vitreous body and the crystalline lens. The aqueous humor fills up the spaces between the crystalline lens and the iris,[1] and (extending through the pupil) between the iris and the cornea (Fig. 426); these spaces being termed the *posterior* and the *anterior* chambers of the eye. (Figs. 426 and 428.)

The *aqueous humor* is so called from its resemblance to pure water. It is afforded by the epithelial cells covering the anterior and the posterior chambers of the eye, and is very readily reproduced if removed experimentally in the lower animals. It is one of the three refracting media of the eye.

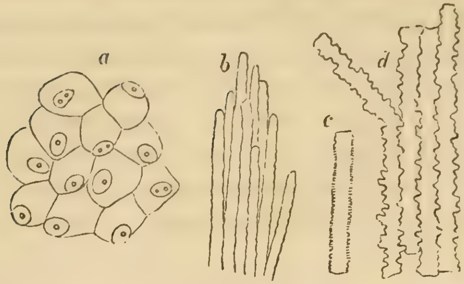
The crystalline lens and the vitreous body require a special description.

1. *The Crystalline Lens.*

The crystalline lens consists of concentric laminæ arranged like the coats of an onion (Fig. 432), which are composed of elongated, flat, hexahedral tubes (*not fibres*), $\frac{1}{4800}$ to $\frac{1}{2400}$ of an inch broad, and $\frac{1}{13333}$ to $\frac{1}{857}$ of an inch thick, perfectly transparent, and containing a clear, viscous, albuminous fluid. Each tube is slightly

[1] It is very doubtful if any space naturally exists between the iris and the lens.

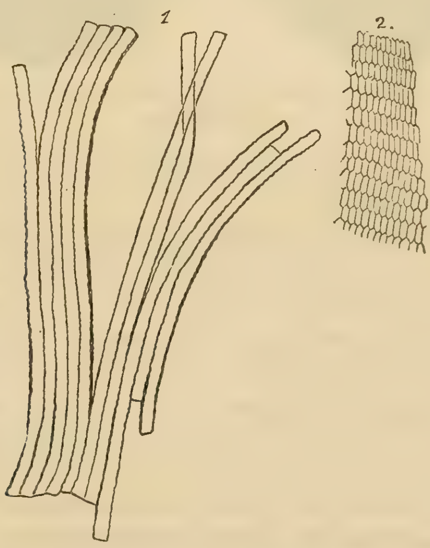
Fig. 432.



a. Cells connecting the body of the lens to its capsule (human). *b.* Tubes of the lens, with slightly sinuous edges. *c.* Tubes from the ox, with finely serrated edges. *d.* Tubes from the cod; the teeth much coarser. (Magnified 320 diameters.)

serrated at its edges (Fig. 432), and, as it enters into the formation of a lamina, is surrounded by six others. Thus their transverse section resembles a wall built of hexagonal bricks. (Fig. 433.) The serrations are much more beautifully marked in the lower

Fig. 433.



Tubes of the lens. 1. From the ox, with slightly toothed borders. 2. Transverse section of the lenticular tubes of man.—Magnified 350 diameters. (*Kölliker.*)

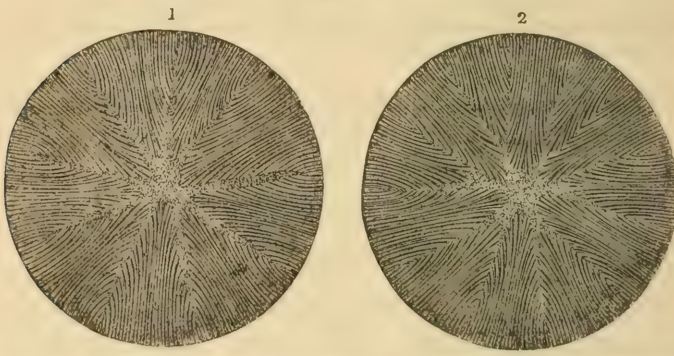
animals, especially fishes. (Fig. 432, *d.*) The tubes are more solid, slender, and opaque in the central part of the lens.

The tubes lie with their sides parallel to the surface of the lens,

and, being here less coherent than on their largest surfaces, they are more easily separated into laminæ in this direction.

In the separate lamellæ, both the superficial and the deeper tubes generally radiate from the centre of the lens towards the margin, and then curve round upon the other surface, anterior or posterior; but never extend through the entire semi-circumference of the lens. Indeed, a peculiar appearance called the "star" is produced where they terminate on both surfaces of the lens, as shown by

Fig. 434.



Lens of the adult (after Arnold), to show the "star." 1 Anterior aspect. 2. Posterior aspect.' (*Kölliker.*)

Fig. 434. In these there are no tubes, but a substance partly clear and partly finely granular.

The *capsule* of the lens is formed of simple membrane, and is perfectly transparent and very elastic. It admits neither vessels nor nerves to the completely inclosed lens. It is, however, readily permeable to fluids; and it is the transmission through it, after death, of the aqueous humor of the eye, that mainly gives rise to the "liquor Morgagni"—this not being a normal condition, as has been supposed. A single layer of clear, polygonal, epithelial cells, however, covers the anterior half of the inner surface of the capsule; and these, disintegrated, also help to form the "liquor."

Chemical analysis (of the lens) detects the presence of crystalline, described on page 97. It contains about 58 per cent. of water.

The crystalline lens is not vascular at any period of its development. The capsule is so, however, during early fœtal existence; the central artery of the retina expanding upon its posterior layer (after having traversed the vitreous humor), and sending branches

round its margin to unite with twigs from the ciliary processes upon the anterior surface. The loops of the latter gradually retire from the centre towards the margin, and finally the posterior layer also ceases to be vascular. In inflammatory conditions, however, the vascularity may return.

Uses.—The crystalline lens is of the highest importance as one of the refracting media of the eye.

The fibres of the crystalline lens are, apparently, *developed* originally from cells like those shown in Fig. 432.

The *growth* of the lens is, probably, secured by the absorption, through its capsule, of the aqueous or the vitreous humor. (*Kölliker.*)

The crystalline lens has been, though very rarely, *regenerated*, in very young subjects, after its entire extraction.

An opacity of the crystalline lens, or its capsule, or both at the same time, constitutes *cataract.*

2. *The Vitreous Body.*

This body (Figs. 426 and 431) is a close web of transparent fibres, enveloping a transparent fluid in its meshes; and is inclosed in a simple membrane (membrana hyaloidea), on the exterior of which vessels are distributed. (*Todd and Bowman.*) The central artery of the retina passes through the centre of the vitreous body, but does not give off any branches to it. Its nourishment is probably in part sustained by the plexiform arrangement of vessels constituting the ciliary processes. (Fig. 430.)

The fluid of the vitreous humor is a weak, watery solution of salts and albumen.

During fœtal life, this body is supplied with vessels in its interior also.

Use.—This is also one of the refracting humors of the eye.

The *eyeball* is *covered* anteriorly by the conjunctiva, which is essentially a mucous membrane; though the portion in front of the cornea is merely a compound scaly epithelium, without a corium. This also continues over the sclerotica, where there is a pale, thin corium, without any papillæ, and attached to the sclerotic by a loose and abundant areolar tissue containing fat-cells. The mem-

brane is reflected from the selerotica above and below, and lines the lids. The latter also have a compound scaly epithelium. Papillæ occur on the palpebral conjunctiva, especially towards the line of reflection, where they are $\frac{1}{120}$ of an inch long. *At* the line of reflection they are sometimes even $\frac{1}{60}$ of an inch. (*Krause.*) Their enlargement constitutes the *granular lid*, so called; the lower lid being most frequently affected, since they are most abundant there.

The *eyelids* consist of—1*st*, the mucous membrane just described; 2*dly*, the fibres of the levator palpebræ superioris, and the orbicularis palpebrarum; and, 3*dly*, the skin, only $\frac{1}{60}$ to $\frac{1}{96}$ of an inch thick: all these elements being connected together by a lax connective tissue. The skin is furnished throughout with minute sweat-glands ($\frac{1}{120}$ to $\frac{1}{144}$ of an inch), and generally with minute hairs and sebaceous glands. The free borders of the lids are bounded by the *tarsi*, improperly termed *tarsal cartilages*. They consist merely of fasciculi of white fibrous tissue, though occasionally containing a few minute cartilage-cells. Into their free edges the cilia (eyelashes) are inserted, immediately in relation with the Meibomian glands. (Fig. 133.)

But for a full description of the remaining appendages of the eye (the muscles and the lachrymal passages, &c.) the works on descriptive anatomy may be consulted, since they present no peculiar histological elements. For the very numerous pathological conditions to which this organ is liable, reference must be had to the special treatises on this subject.

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Page 44, 2d line from bottom, for "*pneumonic*," read "*pneumic*."
" 71, 2d line " " of foot note, for "*proportions*," read "*propositions*."
" 236, line 12th, and page 508, line 17th from bottom, for "*when*," read "*where*."
" 265, 4th line from bottom, for "$\frac{1}{6}$," read "$\frac{1}{16}$."
" 425, line 10th, for "*its*," read "*their*."
" 428, lines 6th and 15th, for "*Pacchionian*," read "*Pacinian*."
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